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IMPROVING SOFTWARE QUALITY ASSURANCE METHODS

Systems Architects, Inc.

James J. Davlin and Margaret Weedon

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This effort was co-ordinated among Rome Air Development Center (RADC), Defense Logistics Agency Headquarters (DLA Hq), Air Force Contracts Management Division Headquarters (AFCMD Hq), and Electronic Systems Division (ESD). System Architects, Inc. (SAI) performed this effort and has examined, analyzed, and evaluated the current software acquisition and contract administration management documents, software quality assurance tools, techniques and communication methods and has developed a series of

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recommendations for improved methods for assuring quality software.
These improved methods encompass the entire software development life
cycle which consists of five phases: (1) Requirement Analysis, (2) De-
sign, (3) Code and Checkout, (4) Test and Integration, and (5) Operation
and Maintenance. SAI examined relevant documentation, conducted inter-
views and compiled the results from a comprehensive questionnaire as the
basis for the analysis, evaluation and recommendations which can be found
herein.

SAI's recommendations for improved methods of assuring quality software
are classified in four groups: (1) Establish clear, unambiguous Govern-
ment Software Quality Assurance Guidance Documents, (2) Includes Software
Quality Assurance Functions in all phases of the Software Development
Life Cycle, (3) Improve communication methods and model documents prim-
arily by mutual agreement regarding allocation of functional responsi-
bilities between CAO's and Program Offices, and (4) Provide up-to-date
training and people skilled in software to government SQA organizations.

This effort should be viewed as a catalyst for continuing endeavors by
ESD, AFCMD, and DLA in their necessary commitment to Software Quality
Assurance.

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MANAGEMENT SUMMARY

The Department of Defense (DoD) perceives software as an
increasing cost which must be harnessed and controlled. This
perception was first evident in the mid-1970's when DoD Direc-
tive 5000.29, Management of Computer Resources in Major Defense
Systems, and DoD Instruction 5000.31, Interim List of DoD Ap-
proved High Order Programming Languages, were issued. Another
related undertaking in the later 1970's and still in the Research
& Development stages is an effort to standardize on computer
architectures with the intent of reducing costs. Recently, a new
DoD Software Technology Initiative has been assembled aimed at
order-of-magnitude improvements in DoD's capabilities to develop
and maintain software. The need for this is evident because the
cost for software within DoD is projected to grow from $3 billion/
year currently to $30 billion/year over the next decade.

The services responded to DoD direction by issuance of
regulations, standards, and specifications, aimed at controlling
software development. The responses were, for the most part, on
an individual, service and agency basis and resulted in a pro-
liferation of software acquisition guidelines, management pro-
cedures and standardization efforts. This caused some overlap
and redundancy. To rectify this, a Joint Logistics Commanders
(JLC) Software Workshop was convened from April 2 to April 4, 1979.
Four panels were set up: (1) Panel A, Software Acquisition/
Development Standards, (2) Panel B, Software Documentation, (3)
Panel C, Standards for Software Quality, and (4) Panel D, Software
Acceptance Criteria. The panels issued findings and recommen-
dations. The JLC Joint Policy Coordinating Group for Computer
Resource Management then asked the Computer Software Management
(CSM) Subgroup to develop a plan of action for solving the
problems identified by the four (4) panels above. This plan is
being implemented.

This effort, "Improving Methods of Assuring Quality Software", was conceived as a result of the JLC study and is related to the CSM plan of action. It was a co-ordinated effort among Rome Air Development Center (RADC), Defense Logistics Agency Headquarters (DLA Hq), Air Force Contracts Management Division Headquarters (AFCMD Hq) and Electronic Systems Division (ESD). RADC contracted with Systems Architects, Inc. (SAI) to perform the effort. The findings will be forwarded to the Air Force representative for consideration in the JLC program.

Systems Architects, Inc. (SAI) has examined, analyzed and evaluated the current software acquisition and contract admini-stration management documents, software quality assurance tools, techniques and communication methods and has developed a series of recommendations for improved methods of assuring quality soft-ware. These improved methods encompass the entire software devel-opment life cycle which consists of five phases: (1) Require-ment Analysis, (2) Design, (3) Code and Checkout, (4) Test and Integration, (5) Operation and Maintenance. SAI examined relevant documentation, conducted interviews and compiled the results from a comprehensive questionnaire as the basis for the analysis, evaluation and recommendations which can be found herein.

SAI's recommendations for improved methods of assuring quality software are classified in four classes: (1) Establish clear, unambiguous Government Software Quality Assurance Guidance Docu-ments, (2) Include Software Quality Assurance Functions in all phases of the Software Development Life Cycle, (3) Improve communi-cation methods and model documents primarily by mutual agreement regarding allocation of functional responsibilities between CAO's and Program Offices, and (4) Provide up to date training and people skilled in software development to government SQA organizations.

Establishing clear, unambiguous government software quality assurance plans is a prerequisite for performing the software quality assurance function. Most current plans have evolved out of the hardware quality control area. The adaptation of a hard-

ware quality control plan to a software quality assurance plan does not meet all requirements due to the two fundamentally different natures of hardware and software. Hardware quality control is oriented toward the production and manufacturing phase of a reproduceable product. In software quality assurance, there is a need for involvement during the entire software development life cycle since the product can be considered to be produced only one time. Software quality assurance is a separate issue and a unique discipline and therefore requires separate unique guidance documents.

Including the software quality assurance function within all phases of the software development life cycle is essential to the development of quality software. The government's SQA representatives should monitor the implementation of the contractor's SQA plan to ensure all SQA functions are covered during the appropriate phases of the software development life cycle. During the Requirements Analysis Phase, the government SQA organization should assist in the review of the requirements specification to help analyze and evaluate the software requirements for acceptability. During the Design Phase, the government SQA organization should work with the software development team to recommend and then maintain standards, procedures, and plans affecting the balance of the development process. During the Code and Checkout Phase, numerous SQA monitoring functions are conducted to verify that development personnel have implemented all requirements and complied with project standards. During Testing and Evaluation, the SQA organization should review project test plans and procedures. The review should trace requirements from the specification to the test plans and test reports. During Operation and Maintenance, the SQA organization should maintain software trend analysis studies to measure the frequency of defects as an aid to the maintenance group.

Communication methods within and among SPOs and CAOs should

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be improved. Currently ESD, DLA and AFCMD all operate on different vocabularies. This difference has been recognized at Air Force Headquarters level, and ESD and AFCMD are currently working toward closer models and vocabularies. Delegation of functions for SQA by the Program Office through Memoranda of Agreement (MOAs) and Letters of Delegation (LODs) sometimes causes problems because the CAO does not have the resources to perform a function. The SPO and CAO need to "communicate" to cover all functions before the formal agreement of delegation of functions before either a MOA or LOD is written. This communication should continue when necessary throughout the contract.

Providing up to date training and people knowledgeable in software development to government SQA organizations is a must if the above three recommendations are to be carried through to implementation. A member of a SQA organization representing the government to a software development contractor will provide his important service to the government only if he has the technological "know-how". Government SQA personnel must have knowledge in software development to be effective.

This required knowledge for government SQA organizations can be gained either through training of the current staff or hiring from the outside. It should be recognized that in competing for this knowledge and skill, the government is competing for scarce personnel. As part of this effort, SAI has prepared and delivered a "Training Outline" customized for POs' and CAOs' training needs under separate cover.

This effort should be viewed as the catalyst for continuing endeavors by ESD, AFCMD and DLA in their necessary commitment to SQA.

Again, the projected cost for software in 1990 within DoD is $30 billion. Many of the programs being monitored in the field are just now experiencing contemporary software system develop-

ment practices. New practices evolving from the R & D community are on the horizon and others can be expected in this rapidly changing and dynamic field. The DoD Software Technology Initiative should serve as a motivating factor.

There are reports that users tasked with the maintenance of operational software are saturated to the point where they cannot see how they will be able to accept and maintain new software. Software maintenance costs can be expected to continue to be the largest part of the $30 billion. Effective SQA will reduce this cost.

Adequate and modular training programs, opportunity for personnel advancement, better planning, and communication between POs and CAOs, are some of the necessary ingredients for insuring the delivery of high quality software and alleviating what will otherwise be an unmanageable maintenance problem.

Implementation of these recommendations will provide DoD with an increased probability of receiving and maintaining quality software.

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SECTION I

INTRODUCTION AND WORKPLAN

1.1 INTRODUCTION

The Electronic Systems Division (ESD) Project Offices
(POs) Hanscom AFB, MA; the Air Force Contract Management Divi-
sion (AFCMD), Kirtland AFB, NM; and its field Air Force Plant
Representative Offices (AFPROs); and the Defense Logistics
Agency (DLA), Alexandria, VA; and its field offices; Defense
Contract Administration Services Plant Representative Offices
(DCASPROs) and Defense Contract Administration Services Manage-
ment Areas (DCASMAs) have an increased demand for tools, tech-
niques and methods to ensure that the Government is receiving
acceptable software. The current software quality tools, tech-
niques and methods are in need of improvement. In order to
improve the current software quality tools, techniques and
methods, the Rome Air Development Center (RADC) contracted
with Systems Architects, Inc. (SAI) to perform an analysis and
evaluation of current software quality tools, techniques and
methods and make recommendations for their improvement. The
Statement of Work for this contract was co-ordinated among
RADC, DLA Hq., AFCMD Hq., and ESD/TOIQ, recently redesignated
ESD/TOEA.

1.2 OBJECTIVE

The objective of this study was to analyze, evaluate and
improve the software quality tools, techniques and methods used
by ESD, DLA and AFCMD. These improved software quality tools,
techniques and methodologies will enable the ESD Project Offices
to provide more effective guidance to the acquisition manager of
contracts for software development; enhance the ability of the
ESD Project Offices and Contract Administration Offices (CAOs)
(Hq. of AFCMD and its AFPROs and Hq. DLA and its subordinate
organizations) to monitor the progress of software quality
during the different phases of the software development life
cycle; and better the Government probability of receiving

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software of acceptable quality from defense contractors.

1.3 SAI's WORKPLAN

SAI performed this study through the completion of the following six tasks as scheduled: (Task I) Project Kickoff and Background Research, (Task II) Structured Data Collection Instruments and On-Site Interviews; (Task III) Questionnaire Development and Dissemination; (Task IV) Analysis of Questionnaire and Follow-up Action; (Task V) Analysis and Evaluation of Integrated Research Results Leading to Comprehensive Recommendations and; (Task VI) Final Report.

1.4 STUDY METHODOLOGY

SAI designed a highly structured methodology for this study of SQA tools, techniques and methods. By insisting on a structured and a vigorous approach in the initial stages of the project, individual project tasks were created which integrate efficiently to yield the desired result. This subsection is organized according to the six tasks.

1.4.1 Task I - Project Kick-Off and Background Research Investigation/Analysis

There were three major objectives of this first task: (1) Conduct meetings to introduce project personnel to the Review Panel composed of members from RADC, DLA, ESD, and AFCMD and finalize project work plan and schedule; (2) Review Government furnished materials including regulations, manuals and standards to determine the appropriate boundaries for the remainder of the study; and (3) Investigate software acquisition and contract/management guidance documentation, related specifically to software quality. This investigation represented the major level of effort in this task. It was one of three project research efforts designed to gain a clear understanding of current software quality tools, techniques and communication methods before proceeding to the integrated analysis. This investigation of documents also served as a baseline for the preparation

of the other two research tools of this project, the
Structured Data Collection Instrument and the Structured
Questionnaire. Throughout the contract updated materials
were supplied by the Review Panel. A preliminary analysis
of the guidance documents was submitted to the Contracting
Officer's Technical Representative (COTR).

1.4.2 Task II - Structured Data Collection Instrument Development and On-Site Interviews

There were two major objectives of this second task:
(1) Develop Forms for a Structured Data Collection Instru-
ment and (2) Conduct on-site reviews and interviews using
this Structured Data Collection Instrument. The SAI survey
team conducted interviews with government personnel in
accordance with the schedule arranged by RADC. At the com-
pletion of this task a preliminary analysis of the reviews
and interviews was submitted to the COTR.

1.4.3 Task III - Questionnaire Development and Dissemination

There were two major objectives of this third task:
(1) Develop a questionnaire with instructions and (2)
Disseminate the questionnaire to the organizations identi-
fied by the Government. This questionnaire was developed
based on the background research of Task I and preliminary
analysis of the on-site reviews and interviews of Task II.
This questionnaire was the third of three research tools
used by SAI in this project. SAI met with COTR to gain
approval of questionnaire and dissemination strategy.

The questionnaire was disseminated to DLA, ESD
and AFCMD organizations identified by the Government during
the questionnaire approval meetings. The completed ques-
tionnaires were returned to SAI for compilation and anal-
ysis.

1.4.4 Task IV - Analysis of Results of Questionnaire and Follow-up Action

There were three major objectives of this fourth

task: (1) Compile the results of the returned question-
naires; (2) Follow-up action on incomplete or unreturned
questionnaires; (3) Analyze results of all completed
questionnaires. SAI compiled the results of the question-
naire in workbooks that lead to customized analysis for
each organization.

At this point, all of the research was completed
and a preliminary analysis was completed in three areas:
(1) Investigation of Documents, (2) Structured Data Col-
lection Interviews and (3) Questionnaire Results. SAI
prepared and submitted an Interim Technical Report con-
cerning these areas.

1.4.5 Task V - Analysis and Evaluation of Integrated
Research Results Leading to Comprehensive
Recommendations

There were four major objectives to this fifth task:
(1) Integrate the results of all prior research; (2)
Analyze and evaluate integrated results; (3) Identify
areas for improvement; and (4) Make specific recommen-
dations.

The first step in this task was the integration of
the results obtained from the three research tools; (1)
Investigation of Documents, (2) Structured Data Collection
interviews and (3) Questionnaire. This integration provided
the starting point for a total analysis.

SAI analyzed the integrated results for three groups:
DLA, ESD, and AFCMD. SAI structured the analyses using a
"Software Quality Analysis Form". The form structured in-
formation such as: (1) Description of tool, technique or
communication method, (2) Current Status, (3) Requested
Changes, (4) Reason behind request for change. This in-
tegrated analysis is presented in Section III of this
report.

SAI evaluated the integrated research results for
the three groups. SAI's evaluation was performed by first,

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developing evaluation criteria and second, by designing a "Software Quality Evaluation Form" that reflected the evaluation criteria.

This evaluation was structured to correspond with the analysis form. The "Software Quality Evaluation Form" structured information such as: (1) Current opinion, (2) Advantages, (3) Disadvantages, (4) Advantages of change and (5) Disadvantages of change. This evaluation is presented in Section IV of this report.

SAI identified "Areas for Improvement". SAI structured a "Software Quality Improvement Form". This Form corresponded with the evaluation form. The "Software Quality Improvement Form" structured information such as: (1) High payback changes, (2) Areas for Improvement and (3) Potential Requirements. These "Areas for Improvement" are presented in Section V of this report.

SAI's recommendations were developed using a "Software Quality Recommendation Form". This Form structured the information such as: (1) Effort required to meet Potential Requirements, (2) Benefit and, (3) SAI's Recommendations. These recommendations are presented in Section VI of this report.

1.4.6 Task VI - Final Report

There were two major objectives to this sixth and final task: (1) Completion and submittal of the Final Report and (2) Submittal of a training course outline. The training course was submitted under separate cover to reflect the recommendations. This document is the Final Report and is structured to reflect the methodology of Task V. The analysis, evaluation, areas for improvement and recommendations are presented in narrative addressing all the points brought out by the four "Form" methodology of Task V.

1.5 OTHER CONSIDERATIONS

Throughout the report, those persons engaged in the work of software quality assurance are referred to as "software quality assurance personnel", a term consistent with that used throughout the industry.

"Management" personnel refers to those staff members who determine policies, manage software quality assurance programs or supervise other staff members.

"Operations" personnel refers to those staff members who monitor contractor software quality assurance.

In addition, the subject of the report is Government software quality assurance practices, procedures and personnel. In instances where discussion refers to contractors, "contractor' has been specifically stated.

SECTION II

ORGANIZATION PROFILES OF STUDY PARTICIPANTS

2.1 PARTICIPATING ORGANIZATIONS

Representatives of the following organizations participated
in this study during both the on-site interview and question-
naire data collection efforts:

- Defense Logistics Agency (DLA)

- Defense Contract Administration Services Management
  Areas (DCASMAs)

- Defense Contract Administration Services Plant
  Representative Offices (DCASPROs)

- Electronic Systems Division (ESD/TO)

- ESD System Program Offices (SPOs)

- Air Force Contract Management Division (AFCMD)

- Air Force Plant Representative Offices (AFPROs)

Figures 1 through 3 illustrate the organizational struc-
tures (as of November, 1980) of the Defense Logistics Agency,
the Air Force Contract Management Division and the Electronic
Systems Division with their respective subordinate organ-
izations.

Since the time of the data collection effort, the Electronic
Systems Division's Technical Operations section has reorganized,
specifically in the software and hardware directorates. Changes
are not reflected on a new organization chart but the area of
reorganization can be determined by a comparison of Figure 3
with Figure 4. The directorate of Engineering and Testing (old
TOE) and the Directorate of Computer Systems Engineering (old
TOI) have combined talents into the new TOE, which includes the
following four subgroups: (1) TOEA which closely approximates
the old TOIQ, (2) TOEE which closely approximates the old TOIT,
(3) TOET, predominantly a hardware division, and (4) TOEO, a

resource management office.

TOEA is responsible for software quality assurance, training and computer resource estimation (i.e., sizing and timing).

TOEE controls programs such as software metrics, and computer security, and supports the program for Ada development.

TOET provides experts in all areas of hardware functions, including document reviews.

TOEO is the support office, controlling human resource management.

The reorganization tends to place less emphasis on software quality assurance. However, the efforts of software quality assurance specialists have increased to compensate for this decrease in emphasis.

2.2 SELECTION OF PARTICIPANTS

Organizations specified in the Request for Proposal for on-site visits and personnel interviews were:

- Headquarters/Air Force Contract Management Division

- Two Air Force Plant Representative Offices, (1) AFCMD Detachment 38, General Electric Company, RESD&SD, Valley Forge, PA, (2) AFCMD Detachment 45 (EN), Westinghouse Electric Corporation, Baltimore, MD

- Headquarters/Defense Logistics Agency/QES

- DCASPRO, GTE/Sylvania, Needham, MA

- ESD/TOIQ and one SPO, COBRA/JUDY

Individual participants interviewed from these organizations were selected by representatives from the Defense Logistics Agency, the Electronic Systems Division and the Air Force Contract Management Division.

Questionnaire respondents were selected from the headquarters of the Defense Logistics Agency, the Electronic Systems Division, the Air Force Contract Management Division and from

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their respective subordinate organizations. Personnel from the management and operations levels at each location were selected.

2.3 HUMAN RESOURCES PROFILES

A tracking of the number of personnal authorized and assigned for software quality assurance over a five-year period yielded the following profile:

- Within the Defense Logistics Agency and the Air Force Contract Management Division there has been a minimal increase in the number of personnel authorized and assigned to software quality assurance.

- Within the Electronic Systems Division there has been little or no increase in the number of personnel authorized and assigned to software quality assurance.

Overall, the increase in the number of personnel assigned to software quality assurance indicates that more emphasis is being placed on software quality assurance. However, manpower is still inadequate. Respondents stated that this situation may be alleviated by hiring qualified software quality assurance specialists and/or by providing in-depth training to those personnel who are currently performing software quality assurance activities and have the added advantage of experience in working on Government contracts.

In many cases, the number of personnel authorized for software quality assurance is not available. A key factor affecting the staffing of software quality assurance projects and maintaining staff is turnover. The major causes of turnover within the Defense Logistics Agency, the Electronic Systems Division and the Air Force Contract Management Division are losses to private industry, moves within the agency, military transfers and retirement. Recruitment of appropriately skilled personnel is difficult because the Government is competing with the private sector for similar skills.
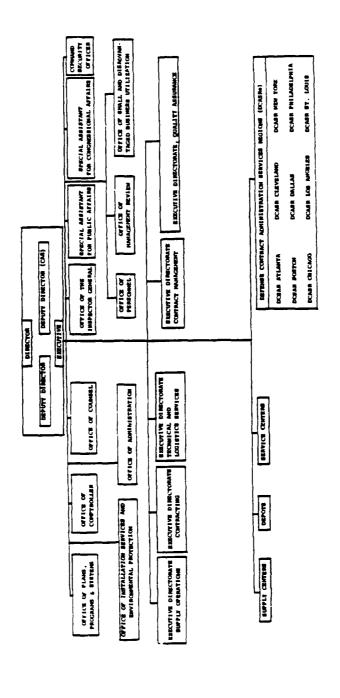
Figure 1. Defense Logistics Agency

*As of November, 1980

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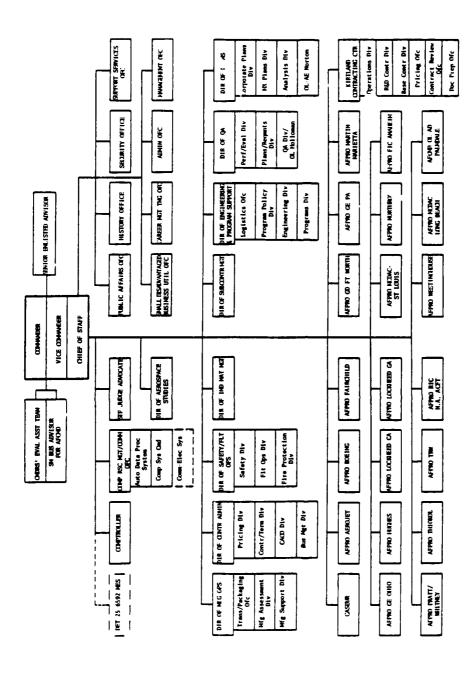
Figure 2. Air Force Contract Management Division (AFCMD)

*As of November, 1980
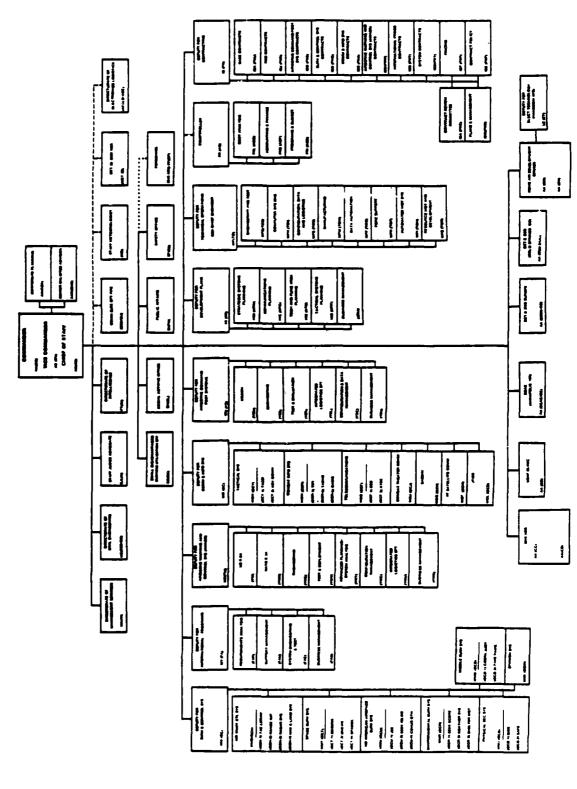
Figure 3. Electronic Systems Division (ESD)

*As of November, 1980

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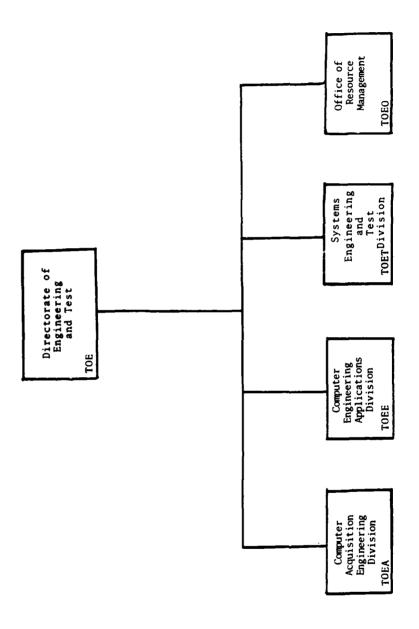
Figure 4. Reorganization of ESD/TOE

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SECTION III

ANALYSIS OF CURRENT SOFTWARE QUALITY

ASSURANCE PRACTICES AND REQUESTED CHANGES

3.1 OVERVIEW

Information concerning current software quality assurance practices within the Defense Logistics Agency, the Electronic Systems Division and the Air Force Contract Management Division was compiled from three sources: (1) Responses from personnel interviewed during on-site visits, (2) Information from questionnaire respondents, and (3) Research of applicable standards, regulations and specifications. In addition, representatives from these three major organizations contributed valuable information based on their own experiences and positions within their respective agencies.

The analysis of all information indicates that software quality assurance practices and associated problems relate to four major areas: (1) Government Software Quality Assurance Guidance Documents, (2) the Relation of Software Quality Assurance to Software Development, (3) Communication Methods and Model Documents, and (4) Training and Staffing.

The following subsections describe by area the current practices and changes requested by members of each organization. Where information is essentially the same for the three organizations, the analysis is consolidated. A summary of requested changes is included at the end of this section. This forms the basis for Section IV, Evaluation of Current Software Quality Assurance Practices and Change Requests.

3.2 CURRENT PRACTICES RELATING TO GOVERNMENT SOFTWARE QUALITY ASSURANCE GUIDANCE DOCUMENTS

The discussion of software quality assurance guidance documents encompasses five areas: (1) Request for Proposal Preparation, (2) Contract Award Negotiations, (3) Memoranda of Agreement/Letters of Delegation, (4) Engineering Change Proposals,

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and (5) Subcontractor Control. These are areas where software quality assurance require aents, provisions and procedures for implementation should be addressed in detail if quality software is expected.

In the Defense Logistics Agency, the primary guidance document for developing a quality assurance management plan is DLAM 8200.1, Procurement Quality Assurance Manual. Section IX, Part 15 "Procurement Quality Assurance For Computer Software" provides direction for developing a software quality assurance management plan.

The overall guidance documents of the Electronic Systems Division is AFR 800-14, Volume I - Management of Computer Resources in Systems, and Volume II - Acquisition and Support Procedures for Computer Resources in Systems. Most respondents stated that there is no guidance document solely for developing software quality assurance management plans, and expressed the opinion that one is needed. At the System Program Office level, the Contractor's Computer Program Development Plan (CPDP) is the primary management plan.

The Air Force Contract Management Division's guidance document for developing a quality assurance management plan is AFCMDR 74-1, Procurement Quality Assurance Program. Chapter 15 provides direction for developing a software quality assurance management plan. There is a new version of AFCMDR 74-1 dated 30 March 1981, but this version was not mentioned by respondents. Other guidance documents used include:

- AFCMDR 178-1, Contractor Management System Evaluation Program (CMSEP)

- AFR 800-14, Volume I - Management of Computer Resources in Systems, and Volume II - Acquisition and Support Procedures for Computer Resources in Systems

In addition AFCMDR 800-1, Contract Management Engineering and AFCMDP 800-2 Contract Management Engineering Guide, both

dated August 1981 have great impact on AFCMD's software quality assurance activities. However, these two documents were not mentioned by respondents as they were not available during the data collection effort.

Most respondents from the three organizations stated that the guidance documents are adequate for making management decisions and for assuring the quality of software but that improvements are needed. All respondents stated that software quality assurance should be more heavily emphasized.

3.2.1 Request for Proposal Preparation

Software quality assurance personnel within the Defense Logistics Agency are not involved in request for proposal preparation.

There is some involvement in request for proposal preparation within the Electronic Systems Division. Criteria used are:

- Request for proposal review guides (for example, ESD/TOI OI800-1);
- User requirements;
- Military standards;
- Available funding; and
- Past experience.

Those who do participate in request for proposal reviews listed the following as valuable contributions to be made by software quality assurance personnel: ensuring that standards and regulations are followed; ensuring good engineering practices, and checking schedule requirements.

There is some involvement in request for proposal preparation within the Air Force Contract Management Division. Participation includes planning, writing and review.

Criteria used in request for proposal reviews are:

- AFCMDR 74-1, <u>Procurement Quality Assurance Program</u>;

- MIL-S-52799A, <u>Software Quality Assurance Requirements</u>;

- MIL-Q-9858, <u>Quality Program Requirements</u>;

- ASD/ESD <u>Software Acquisition Management Guidebooks</u>;

- Requests of PCOs; and

- Past experience.

Problems occur when suggestions are made by software quality assurance personnel and no response is received from the development team. The Air Force Contract Management Division is currently working on a "feedback loop" procedure to enhance the communication system. AFSCR 800-42, <u>Program Office/AFCMD Interface</u> was issued on 1 May 1981 which "prescribes the policy for establishing program office/ AFCMD interface during the conceptual phase and for providing AFCMD specialized support for AFSC program offices throughout the acquisition cycle".

3.2.2 Contract Award Negotiation

In the Defense Logistics Agency and the Air Force Contract Management Division there is no involvement in contract award negotiations. In the Electronic Systems Division those few who do participate in negotiations listed as procedures/guidelines used: matching proposals to technical evaluation criteria and tracing proposals back to corresponding request for proposals.

3.2.3 Memorandum of Agreement/Letter of Delegation

The division of functions between the Program Office

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and the Contract Administration Office is achieved, generally, through the Memorandum of Agreement, Letter of Delegation and Defense Acquisition Regulations (for example, DAR 20-703.3). In the Defense Logistics Agency the division of functions is not always negotiated. Negotiations that do occur range from the time of review of requests for proposals to six months after contract award. Some offices have a Letter of Delegation with a Program Office; some do not. The methods of deciding the division of functions include: (1) Delegation of responsibilities by the Program Office; (2) Contract clause and/or Quality Assurance Letters of Instructions; and (3) Directions of the Program Office through the ACO. In some cases, provisions on software are specified; in others, they are not specified. When modifications of the provisions on software occur it is usually due to:

- Attempts to meet delivery dates,

- Redefinition of DCASMA functions.

Within the Electronic Systems Division there was no consistency in responses regarding the existence of Memoranda of Agreement, Letters of Delegation nor on the provision of software instructions contained in either. Those who were aware of negotiations stated that they occur at times ranging from the request for proposal reviews to the selection of the contractor.

Within the Air Force Contract Management Division the division of functions is usually negotiated at times ranging from the review of proposals to three months after contract award. Regulations/guidelines followed are:

- AFCMDR 800-11, AFCMD Memorandum of Agreement Management System

- AFSCR 74-1, Quality Assurance Program

- AFCMDR 74-1, Procurement Quality Assurance Program

- AFCMDR 178-1, Contractor Management System Evaluation Program

- AFSCP 800-3 A Guide for Program Management (Chapter 22)

- AFR 800-14, Management of Computer Resources in Systems

Some offices have a MOA with a Program Office; others do not. In some cases, provisions on software are specified; in others they are not specified. Occasions when modifications of provisions on software occur include:

- Directions from the Program Office

- Changes in personnel and technical expertise

- Updating as phases of programs change

3.2.4 Engineering Change Proposals (ECPs)

Generally the respondents do not approve Engineering Change Proposals. This is a function of the Program Office which may be delegated. Within the Defense Logistics Agency the DCAS-ACO at the prime may approve ECPs when authority is delegated. The Engineering and Program Support within the Air Force Contract Management Division may also approve ECPs. The effects noted by software quality assurance personnel are increased costs and delays in implementation due to the time lapse between the submittal of Engineering Change Proposals and approval. Air Force Contract Management Division respondents stated that approval for class II ECPs is faster since they usually are delegated this responsibility and do not have to involve the Program Office as with the more complicated Class I ECPs.

3.2.5 Subcontractor Control

Most respondents agreed that subcontractor control is maintained by the prime contractor. Several respondents from the Defense Logistics Agency and the Electronic Systems Division expressed the opinion that visibility of government control over subcontractors is not adequate. Air Force Contract Management Division respondents expessed much dissatisfaction with subcontract management. Contractors should maintain control via reviews, monitoring and reports; this is not always done.

3.2.6 Requested Changes Concerning Software Quality Assurance Guidance Documents

Table 1 illustrates all specific changes requested by respondents for the improvement of government software quality assurance guidance documents and related areas. The organizations from which a change request originated are indicated in the appropriate cell.

TABLE 1.   REQUESTED CHANGES CONCERNING GOVERNMENT
SOFTWARE QUALITY ASSURANCE GUIDANCE DOCUMENTS

Organizations Requesting Changes			
Requested Changes	DLA	ESD	AFCMD
Place greater emphasis on government soft-ware quality assurance programs	X	X	X
Develop a DOD-wide guidance document			X
Develop new guidance documents	X		X
Revise existing guidance documents by expand-ing the software quality assurance sections	X	X	X
Revise plans as requirements change	X	X	
Provide more tools	X		
Include software quality assurance personnel in the early stages of acquisition	X	X	X
Hire evaluators with software oriented skills	X	X	X
Provide for clear definitions of responsi-bility			X
Improve AFCMDR 800-11			X

3.3 RELATION OF SOFTWARE QUALITY ASSURANCE TO SOFTWARE DEVELOPMENT

In the discussion of the relationship of software quality assurance to software development, the following areas are integrated:

- Life Cycle Models

- Configuration Management

- Baselining

- Reviews and Audits

- Documentation

- Tools and Techniques

Although treated as isolated entities during the interview sessions and in the questionnaire, they are areas that should not be considered alone in software development planning, in life cycle model construction or in software quality assurance management planning.

3.3.1 Life Cycle Models

Based on _interviews_ with management personnel at Hq./DLA, the life cycle model is used only for illustration in training courses. Operations personnel from the field stated that use of the life cycle model occurs during procurement, after contract award and in all documentation from the contractors. _Questionnaire_ respondents from both the management and operations levels stated that they work against a life cycle model. The most frequently cited models were the Defense Logistics Agency's and the contractors'.

Within the Electronic Systems Division most respondents use the AFSC life cycle model from AFR 800-14 and AFSCP 800-3. The life cycle model is predominantly an

instruction aid; but, according to the interviews con-
ducted with management personnel, it is only loosely
followed in practice.

Most respondents from the management and operations
level within the Air Force Contract Management Division
either stated that they do not work against a life cycle
model or did not respond at all. Those respondents that
do use a life cycle model cited the AFSC life cycle model
from AFR 800-14 and AFSCP 800-3 and the Contractors' as
the most frequently used.

3.3.2 Configuration Management

Within the Defense Logistics Agency, configuration
management is generally the responsibility of the contractor.
Within the Electronic Systems Division and the Air Force
Contract Management Division, configuration management
responsibilities are shared by the government and the
contractors. The effectiveness of configuration management
plans as they relate to software acquisition management/
software quality assurance was generally rated as adequate.
The need for some improvement was expressed.

The configuration management guideline in use within
the Electronic Systems Division is MIL-STD-483. No guide-
lines were specified by Defense Logistics Agency or Air
Force Contract Management Division respondents.

3.3.3 Baselines

According to interviewees within the Defense Logis-
tics Agency, baselining is not used as a tool. However,
questionnaire respondents from the management and operations
levels stated that they do work with baselines. Only
the operations level respondents specified Functional,
Allocated and Product Baselines.

All respondents within the Electronic Systems Division and some respondents within the Air Force Contract Management Division stated that they do use Functional, Allocated and Product baselines as reference points in their work of software quality assurance. A majority of Air Force Contract Management Division respondents either stated that they do not work against baselines or did not respond to the question.

3.3.4 Reviews and Audits

System audits and reviews are witnessed by some respondents with the aid of guidebooks and the results of previous reviews. Involvement is in the form of observation rather than an active participation. Audits most frequently witnessed are: Physical Configuration Audits and Functional Configuration Audits. Reviews most frequently witnessed are System Design Reviews, Preliminary Design Reviews, Critical Design Reviews, and Formal Qualification Reviews. Other reviews were cited but none are used on a widespread basis.

3.3.5 Documentation

Contractor documentation is reviewed by operations level software quality assurance personnel. A variety of regulations and specifications are referenced but few methods of recording results were cited by the Defense Logistics Agency, the Electronic Systems Division, or the Air Force Contract Management Division.

3.3.6 Tools and Techniques

With the exception of life cycle models and baselines, software quality assurance personnel use very few tools independent of the contractor.

Checklists, both standard and improvised, guidelines and regulations are some of the primary independent tools

used to evaluate procedures. These tools are generally
used to evaluate contractor documentation.

The Air Force Contract Management Division uses
AFCMDR 178-1, Contractor Management System Evaluation Pro-
gram (CMSEP) as a tool to evaluate the contractor's per-
formance. The techniques of this evaluation are highly
structured. Respondents stated that a separate section
on software quality assurance should be incorporated. Some
respondents stated that CMSEP is too detailed and time
consuming and is not needed by skilled specialists. Other
respondents stated that the detailed procedures of CMSEP
are useful for less skilled personnel.

The contractor's use of other software development
tools and techniques is monitored; but none on a widespread
basis. These include: simulators, requirements analysis
tools, library control tools, software metrics, debuggers,
and walkthroughs.

3.3.7 Requested Changes Concerning the Relation of Software
Quality Assurance to Software Development

Table 2 illustrates all specific changes requested
by respondents concerning the relationship of software qual-
ity assurance to software development. The organization
requesting a specific change is indicated in the appropriate
cell.

TABLE 2. REQUESTED CHANGES CONCERNING THE RELATION
OF SOFTWARE QUALITY ASSURANCE TO SOFTWARE DEVELOPMENT

Requested Changes / Organizations Requesting Changes	DLA	ESD	AFCMD
Revise life cycle model to picture accurately the life cycle of software development*	X		
Use the life cycle in planning	X		
Integrate software quality assurance activities with the life cycle model	X	X	
Provide for government enforcement of contractor configuration management plans	X		
Involve experienced personnel in baselining activities	X	X	
Train software quality assurance personnel in software development	X	X	X
Provide more reviews	X	X	X
Address software in Configuration Management Plans			X
Require internal reviews by contractors			X

*At the time of the interviews (November, 1980) at Hq. DLA
 it was stated that the life cycle model was up for revision
 in six months.

3.4 COMMUNICATION METHODS AND MODEL DOCUMENTS

Communication methods vary widely within and between the
Defense Logistics Agency, the Electronic Systems Division and
the Air Force Contract Management Division. Although several
methods are employed, no formal structure is evident. In addition
to Memoranda of Agreement and Letters of Delegation, some of the
communication methods currently in use include telephoning,
briefings, board meetings and panel discussions.

In responding to questions concerning government software

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quality assurance guidance documents and the relation of software quality assurance to software development, respondents either implied that communication methods can be improved or offered specific suggestions for improvement. Informal communication methods (for example, telephoning for advice or assistance) are effective. However, a formalized structure of communication flow is needed in order to make all project staff aware of major responsibilities and functions involved, who is responsible and what is expected.

Table 3 lists all specific changes requested by respondents to enhance communication methods and provide for effective communication flow. The organizations from which requests originated are indicated in the appropriate cell.

Requested Changes / Organizations Requesting Changes	DLA	ESD	AFCMD
Structure the communication system	X	X	X
Require maintenance of records			X
Emphasize coordination between buying activities and software quality assurance			X
Establish points of contact	X		X
Provide definite guidelines and regulations		X	X
Establish frequency of communication	X		X
Provide for more frequent communication		X	
Identify experts who can be contacted for technical assistance		X	

3.5 TRAINING AND STAFFING

Discussion on training and staffing covers four areas: (1) Formal education of respondents; (2) Training courses attended; (3) Orientation provided, (4) Certification programs available.

3.5.1 Formal Education

Formal education is defined as high school, college or university courses completed. These may culminate in or lead to a diploma or a degree or be non-degree related. The average formal education of respondents is described by agency.

3.5.1.1 Defense Logistics Agency

All respondents from the management level have had from two to four years of college education with major areas of concentration in business or management. Less than half of the respondents from the operations level have had from two to five years of college education with major areas of concentration in science or engineering. Although some respondents have had individual computer science courses, none have been trained specifically in this area.

3.5.1.2 Electronic Systems Division

All respondents from the program management level have had four to six years of college education with major areas of concentration in computer science, electronics, business administration or math. All respondents from the operations level have had from two to seven years of college with major areas of concentration in math or computer systems engineering. Only one respondent had taken no formal courses in computer science.

3.5.1.3 Air Force Contract Management Division

All respondents from the management level have had from one to six years of college education with major areas of concentration in some aspect of engineering, math, or science. The majority of

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respondents from the operations level have had from one to seven years of college education. Major areas of concentration include: engineering, math, law, management, quality control, computer science, electronics, physics, and accounting. Although some respondents have had some computer science/ software courses, a greater number have not.

3.5.2 On-The-Job Training

On-the-job training includes courses, seminars, instructions, etc., received by personnel to assist them to develop the skills needed to perform their task assignments. On-the-job training received by respondents is discussed by agency.

3.5.2.1 Defense Logistics Agency

Some training has been received by respondents to assist them in performing software quality assurance functions. This has been attained through public seminars, courses offered within the Department of Defense, DCAS S-36 Procurement Quality Assurance for Computer Software, and courses respondents have taken on their own initiative. DLAM 8220.5, Quality Assurance Intern Program, has been developed by DLA but does not include software quality assurance.

3.5.2.2 Electronic Systems Division

Training in software quality assurance functions has primarily centered on reading some/all of the ESD Software Acquisition Management Guidebooks and attendance at ESD/TOI's Computer Technology Transfer Training Center course on Software Acquisition Management. Other training has been received through seminars, AFIT courses and courses offered within the

Department of Defense.

3.5.2.3 Air Force Contract Management Division

Some training has been received by respondents to assist them in performing software quality assurance functions. Training has been acquired through DCAS S-36 Procurement Quality Assurance for Computer Software, AFCMD Fundamentals of Software Quality Assurance SQA-1, public seminars, and courses within the Department of Defense.

3.5.3 Orientation

Orientation includes any entry level instruction received by respondents to assist them in their software quality assurance functions. Orientation is discussed by agency.

3.5.3.1 Defense Logistics Agency

No respondents from the management level and less than half from the operations level received orientation instruction pertaining to their software quality assurance functions. Among the orientation instructions listed were:

- SQA course, DCAS S-36, Procurement Quality Assurance for Computer Software,

- Section IX, Part 15, of DSAM 8200.1, Procurement Quality Assurance Manual,

- Introduction to other quality assurance personnel on staff,

- Staff assistance in developing Procedure Checklists.

3.5.3.2 Electronic Systems Division

Some respondents received orientation pertaining to software acquisition management/software quality assurance; others did not. Among the orientation instructions listed were:

- ESD/TOI Software Acquisition Management Course,

- USN SQA, Computer Software for Technical Personnel,

- Development, Control and Acquisition.

3.5.3.3 Air Force Contract Management Division

Some respondents received orientation pertaining to software acquisition management/software quality assurance; the majority did not. Among the orientation instructions listed were:

- DCAS S-36, Procurement Quality Assurance for Computer Software,

- AFCMD Fundamentals of Software Quality Assurance, SQA-1

- Internal AFPRO orientation,

- USN SQA, Computer Software for Technical Personnel

- AFCMDR 74-1, Procurement Quality Assurance Program

- Introduction to Software.

3.5.4 Certification Programs

Certification programs according to DLAM 8220.4, Quality Assurance Certification Program are programs that lead to formal recognition that an individual is technically

qualified in a specific area. Electronic Systems Division respondents stated there are no certification programs for software quality assurance specialists. Three respondents from the Air Force Contract Management Division cited 51XX AFSC as a specialty code describing qualifications for officers. Correspondence courses through Extension Course Institute provide some training in computer science.

Within the Defense Logistics Agency conflicting views were expressed. The majority of management respondents stated that there are no certification programs for software quality assurance management specialists. Those who stated there are described the course of action toward certification as formal training, and experience in accordance with DLAM 8220.4, Quality Assurance Certification Program.

Approximately half of the operations respondents stated that there are certification programs for software specialists. The course of action toward certification was described as:

- Courses listed in DLAH 8220.1, Quality Assurance Technical Development Program, Course Catalog,

- Outside training at private institutions,

- S-38, Computer Fundamentals,

- S-36, Procurement Quality Assurance of Computer Software,

- Completion of required or equivalent courses and one year of hands-on experience in the field.

3.5.5 Requested Changes Concerning Training and Staffing

Table 4 illustrates all specific changes requested by respondents concerning training and staffing. The organizations requesting a specific change are indicated in the appropriate cell.

TABLE 4. <u>REQUESTED CHANGES CONCERNING TRAINING AND STAFFING</u>

Organizations Requesting Changes Requested Changes	DLA	ESD	AFCMD

<u>TRAINING</u>
 	
Provide structured training to software
    quality assurance personnel including:
 	
    ●   management oriented courses
	X	X	X

● software engineering	X	X	X
● software quality assurance	X	X	X
Make training available to more personnel	X	X	X
<u>ORIENTATION</u> Conduct seminars/workshops	X		
Include specifications applicable to software	X		
Instruct on software quality assurance system control techniques	X		
Familiarize personnel with contractor organization, methodology and facilities	X		
Work with experienced software managers on a daily basis		X	
Explain the role of the Plant Representative in software acquisition management			X
Instruct on software quality assurance tools and techniques			X
Explain the requirements of MIL-S-52779/			X

Explain software quality assurance funda-
    mentals and management of a
    software acquisition program
			X

<u>CERTIFICATION PROGRAMS</u> Require that certified personnel be assigned to projects		X	
Develop structured certification programs	X	X	X

3.6   SUMMARY OF REQUESTED CHANGES

The following subsections consolidate all requested changes submitted by respondents from the Defense Logistics Agency, the Electronic Systems Division and the Air Force Contract Management Division. Changes are grouped under four major areas: (1) Government Software Quality Assurance Guidance Documents, (2) Relation of Software Quality Assurance to Software Development, (3) Communication Methods and Model Documents, and (4) Training and Staffing.

Generally, all changes requested by respondents are listed. A particular change may have been requested by one person or several respondents. In some cases, requested changes may seem contradictory, but they were submitted from various organizations with different practices and procedures.

3.6.1   Requested Changes For Improvement of Software Quality Assurance Guidance Documents

Requested changes from the Defense Logistics Agency, Electronic Systems Division and the Air Force Contract Management Division concerning software quality assurance guidance documents and related areas are summarized as follows:

- Place greater emphasis on government software quality assurance programs

- Hire software quality assurance evaluators with software oriented skills

- Provide for clear definitions of responsibility

- Improve Memoranda of Agreement/Letters of Delegation

- Revise existing documents by expanding the software quality assurance sections

- Revise plans as requirements change

- Include software quality assurance personnel in the early stages of the acquisition process

- Develop new guidance documents

- Develop a DoD-wide management plan

3.6.2 Requested Changes For Improvements in Relation of Software Quality Assurance to Software Development

Requested changes from the Defense Logistics Agency, Electronic Systems Division and the Air Force Contract Management Division concerning the relation of software quality assurance to software development are as follows:

- Use life cycle model in planning

- Integrate software quality assurance activities with the life cycle model

- Address software in configuration management plans

- Provide for government enforcement of contractor configuration management plans

- Involve experienced personnel in baselining activities

- Provide more reviews

3.6.3 Requested Changes For Improvement of Communication Methods and Model Documents

Requested changes from the Defense Logistics Agency, Electronic Systems Division and the Air Force Contract Management Division concerning communication methods are summarized as follows:

- Structure the communication system

- Provide definite regulations and guidelines

- Emphasize coordination between buying activities and software quality assurance activities by: (1) establishing points of contact and (2) establishing frequency of communication

- Require that records be maintained.

3.6.4 Requested Changes For Improvement of Training and Staffing

Requested changes from the Defense Logistics Agency, Electronic Systems Division and the Air Force Contract Management Division concerning training and staffing are summarized as follows:

3.6.4.1 Training

- Make training avialable to more personnel

- Develop structured training courses in:
    (1) Management of software projects
    (2) Software Engineering
    (3) Software Quality Assurance

3.6.4.2 Certification Programs

- Develop structured accredited certification programs

- Require that certified personnel be assigned to projects

3.6.4.3 Orientation

- Familiarize personnel with contractor organization, methodology and facilities

- Establish communication system and points of contact

- Work with experienced government software managers on a daily basis

- Instruct on software specifications applicable to the particular project

- Instruct on software quality assurance system control techniques tailored to the contract

- Establish the particular tools and techniques applicable to the project.

Respondents were cooperative, brief and frank. Many suggestions and requests for changes were submitted, which were pertinent to a particular organization, division or project. However, throughout the analysis, issues were raised crossing all areas and organizations and these should be addressed. In Section IV, evaluation of the major areas for which changes were requested includes: identification of problems, examination of possible solutions, and suggestions for implementation.

SECTION IV

EVALUATION OF CURRENT SOFTWARE QUALITY ASSURANCE PRACTICES AND CHANGE REQUESTS

4.1 OVERVIEW

From the integrated analysis of current software quality assurance practices and the compilation of changes requested, four major areas of concern are found to exist throughout the Defense Logistics Agency, the Electronic Systems Division and the Air Force Contract Management Division. These areas are:

(1) Government Software Quality Assurance Guidance Documents,

(2) Relation of Software Quality Assurance to Software Development,

(3) Communication Methods and Model Documents,

(4) Training and Staffing.

Concerns, generally, are not limited to any one agency or organization but pervade all three. In the following subsections, criteria for each area are presented. In light of these criteria, the advantages of each requested change are determined.

Implementation of some of the requested changes will create problems that should be considered. The problems are not unique to any one change request, but relate to the entire concept of improving the practices and procedures associated with the software quality assurance areas listed above. A summary of associated problems is presented at the end of each area of discussion.

4.2 PURPOSE OF SOFTWARE QUALITY ASSURANCE GUIDANCE DOCUMENTS

A guidance document serves as a guide for decision making in developing a software quality assurance management plan. Not all elements of a model plan are necessary for all projects; in fact, it is one of the tasks of management to select which aspects of

the activity will be formally planned and controlled and which
will be informal or ad hoc. The selection criteria are simply the
necessity versus the cost. In general, formality is most costly
in terms of time and money; therefore, if it is not necessary, it
should not be exercised. On the other hand, lack of formal plan-
ning and/or controls carries the risk of chaos. These can easily
lead to problems that are far more expensive than the controls
that would have prevented them. In general, a well-written, clear,
concise software quality assurance management plan will:

- Provide for clear division of responsibilities during
  early system acquisition phases,

- Identify appropriate standards/guidelines to be followed,

- Determine appropriate computer software quality
  assurance requirements,

- Develop software quality assurance evaluation procedures,

- Provide for corrective action procedures, and

- Establish an efficient communication system.

In light of these criteria, the following subsections discuss
the advantages of and problems associated with the changes re-
quested in regard to software quality assurance guidance documents.
The purpose is not to address each of these criteria at this time.
Each change request is examined in order to determine areas where
criteria are not being met and where improvements can be made.

4.2.1 Place Greater Emphasis on Government Software Quality Assurance Programs

Many software projects have been unsuccessful because
of an inadequate software quality assurance program. A
greater emphasis on the software quality assurance discipline
is an important aspect for ensuring that computer program de-
sign, code, associated documentation, and performance comply
with contractual requirements. These aims are accomplished
by implementing a system of controls that are applied to all
phases and aspects of the software development process. This

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assumes that specific software quality requirements are clearly specified in requests for proposals and resultant contracts.

The benefits derived from the application of software quality assurance disciplines are directly related to how well the software quality assurance disciplines are defined and put into effect. The value of those disciplines is reflected by the overall efficiency of the development program and the ultimate quality of the software.

Procedures developed for hardware quality assurance do not satisfy the objectives of software quality assurance. Few similarities exist between evaluating the quality of tangible equipment and evaluating software products such as documentation where adherence to documentation standards, and documentation review are the key elements.

The benefits of placing deserved emphasis on software quality assurance are obvious. Requirements will be specified in contracts. Documentation of program design, coding and testing will be structured according to requirements. Errors will be discovered and corrective action will be applied at the earliest appropriate stage. Cost overruns and schedule delays will be reduced and an improved quality software will be the end product.

4.2.2 Provide for Clear Definitions of Responsibility

A most essential factor in the development of management plans is matching tasks to personnel resources. A project cannot develop successfully if the technical expertise for carrying out responsibilities and functions is not available. Managers must be aware of contractual requirements in order to assess that each task falls within the expertise of his or her staff. When Memoranda of Agreement and Letters of Delegation are required, communication between System Program Offices (SPOs) and Contract Administration Offices (CAOs) should be initiated early in the acquisition cycle

and continue throughout the life of the contract in order that personnel needs are accurately assessed and met.

There are several advantages derived from defining responsibilities. The possibility of omitting tasks is limited. Personnel will perform tasks that are within their level of expertise. Needed specialized skills will be determined and delegated or acquired before the project begins. Each staff member will be fully aware of his or her own particular functions and those of other staff members. The result will be an efficiently run project that adheres closely to schedule and cost constraints.

4.2.3 Improve Memoranda of Agreement (MOAs) and Letters of Delegation (LODs)

Memoranda of Agreement and Letters of Delegation that contain specific provisions on software will enforce the accomplishment of contractual requirements. Technical representatives will be assigned according to their expertise and their specific tasks will be outlined in detail. MOAs and LODs will be written based on communication between the SPOs and CAOs. Tasks will not be delegated to CAOs that do not have the expertise available to perform them. This should help SPOs and CAOs in identifying areas of needed training for their personnel.

4.2.4 Revise Existing Guidance Documents

Software quality assurance guidance documents currently in use throughout the Defense Logistics Agency, the Electronic Systems Division, and the Air Force Contract Management Division contain some basic elements but are heavily dependent on procedures already established for hardware. Software is a much more intangible commodity to assess. Yet, the quality of software may determine the success or failure of a project. Stringent controls are necessary throughout software development. These controls can only be exercised through a detailed, structured model plan devised specifically for

software quality assurance. A structured plan, by its very nature, will be detailed, specifically, to software and will integrate the applicable tools and techniques at the appropriate phases of tne life cycle. It would only remain to integrate the individual procedures and controls that are specific to a project.

Expansion of existing guidance documents will build upon past work and integrate with plans already developed. Interruptions, slowdowns or even stoppage of work caused by the introduction of new procedures and acclimating all personnel will be minimal. Adverse cost effects will be less drastic. In addition, personnel will not be subjected to the frustrations and often the resistance involved in adjusting to new procedures and methods when all that is desired is more detail.

4.2.5 Revise Plans As Requirements Change

Not all elements of a model software quality assurance management plan may apply to every software development project, or, depending on the complexity of a project, they may not apply to the same degree. In addition, software quality assurance is receiving greater emphasis in the software industry which is leading to more intensified research to develop tools for enhancing software quality. Resulting advances in technology will be evident by specification of these advances as requirements.

Software quality assurance guidance documents must be structured for the purpose of control and yet be flexible enough to permit adaptability to technological advances and the resultant changes in requirements. In other words, if a guidance document serves as a "guide" in developing software quality assurance management plans, it will be detailed specifically to software, but allow for selection and integration of applicable tools and techniques without a major revision of the plans. If this can be accomplished,

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delays associated with revisions of regulations, specifications and standards should be non-existent.

4.2.6 Include Software Quality Assurance Personnel In Early System Acquisition Stages

Project success depends upon the amount and quality of planning that occurs before the Full Scale Engineering Development Phase. All staff who are to be involved in the project should be represented in planning sessions. There is apparently little/no involvement of software quality assurance personnel in RFP preparation, proposal review, and contract award negotiation. If responsibility for software quality assurance is to be accepted and performed by professionals, then the same level of professionals should be involved in establishing initial specifications, reviewing responses to proposals and ensuring that requirements are included in contracts. Early input from software quality assurance personnel would aid in eliminating future problems. Based on their past experiences with contractor software quality assurance procedures, government software quality assurance personnel can make recommendations which, if incorporated in RFP's, will aid contractors in addressing quality assurance requirements and submitting clearly defined proposals, plans and procedures. Further, at the time of contract award negotiations, continued involvement of software quality assurance personnel will ensure that software quality assurance procedures are not overlooked or that the impact of any de-emphases which are considered are fully understood.

4.2.7 Develop New Model Software Quality Assurance Guidance Documents

There are several advantages in developing new guidance documents specifically for software quality assurance. Development of a new model plan will eliminate the problems which have arisen by following hardware oriented procedures to assure quality software. Contractors are often dependent on government contracts. Therefore, if the government

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initiates a planning effort in this area, contractors will be likely to follow suit. Rather than depend on contractors to develop software quality assurance plans to meet contractual requirements, the government should take the lead in requiring software quality controls to meet the advances in current technology and reduce rising software costs.

As the focus on software quality assurance increases, emphasis should be placed on formation of a separate group responsible for quality related concerns and detached from the developmental group. Personnel skilled in software areas will be needed to implement the new software quality assurance plans. They can be made available through recruitment, or through the development of formal structured training programs to enhance the technical expertise of those software quality assurance personnel who have been trained in other areas, for example, hardware.

4.2.8 Develop DoD-Wide Model Software Quality Assurance Management Plan

One internal tri-service operating procedure for assuring software quality provides distinct advantages. A standardized plan will enable the government to develop a standardized contract strategy with regard to software quality assurance. Contractors will become accustomed to standard government operating procedures for evaluating the quality of software. Areas that formerly may have been deemphasized will receive greater attention. For example, in the development of a standardized contract strategy, subcontractor control procedures for software quality assurance will be specified in greater detail. Control on the part of the government and the contractor will be more visible.

Memoranda of Agreement and Letters of Delegation will improve. SPOs from the three services will develop standard practices in communicating with all CAOs. The resulting MOAs/LODs will be written with greater facility.

4.2.9 Problems Associated With Requested Changes Concerning Government Software Quality Assurance Guidance Documents

Placing greater emphasis on software quality assurance may result in increased costs initially. If software quality assurance requirements are specified by contract, contract funding must reflect this. Adjustments may have to be made in project schedules. Additional requirements regarding software quality assurance and evaluation procedures may necessitate lengthening the time alloted for project completion. However, through specifying software quality assurance requirements by contract, reviews and evaluations will discover errors at the earliest appropriate stage. This will result in reducing the costs that later error detection may entail. Early error detection and corrective action will also minimize schedule delays.

Two factors must be determined:

(1) Will the additional costs incurred by specifying requirements in the contract be offset by the cost savings that will result from early error detection?

(2) Will the end product of a greater quality of software justify an increase in costs?

The development of new software quality assurance guidance documents within each organization will require the combined efforts of personnel at all levels. This, in turn, will involve the absorption of time that ordinarily would be given to other work. Inadequate manpower is already a common complaint. To release personnel from their software quality assurance tasks may be detrimental to the software products. To hire new personnel as replacements may not be feasible. To assign tasks to other software quality assurance specialists may be to overload already overworked staff. This, too, would be detrimental to the software products.

4.2.9 continued

An alternative solution is to hire the services of outside consultants to develop new software quality assurance guidance documents. The primary factor is cost. The cost of hiring outside consultants must be weighed against the cost of using in-house personnel and the possible effects on software quality assurance work that must continue.

To disregard existing plans may result in the loss of valuable work that has already been generated and only requires further development. The resultant product may involve a duplication of time, effort, and plans that, again, already exist and only need expansion.

Expansion of the software quality assurance sections of existing guidance documents will involve the same resources and attendant problems as those stated above. Decisions will have to be made regarding the use of in-house personnel or hiring outside consultants. However, the total effort may not be as great and the total cost may be less expensive. It is important for each organization to consider beforehand the elements that are lacking in their current guidance documents as determined by this study, and the amount of effort that will be involved in a revision. It is possible that revision will evolve into the development of new documents and the necessary resources for this work should be pre-planned.

The development of a DoD-wide model software quality assurance management plan will require intensive planning efforts. Representatives from all organizations concerned must be included. The groundwork in this direction was undertaken at the Joint Logistics Commanders (JLC) Software Workshop held in April, 1979. Recommendations and plans for implementation are already developed. Costs of implementation may be considerable both in development of uniform guidance documents, regulations, standards and procedures, and in implementation within all organizations. Several factors must be considered:

- Will the costs of developing and implementing DoD-wide plans and procedures regarding software quality assurance be offset by eventual reduced costs in software development?

- Will the costs involved in revising existing documents be greater than, equal to, or less than developing new documents within each organization?

- Can the determination be made as to which plans, DoD-wide or specific organization plans, will effect a greater quality of software?

4.2.10 Summary

Whether or not existing plans are expanded, new plans are developed or a uniform DoD-wide plan is adopted, it is essential that a software quality assurance guidance document become a unique document. As such it will contain:

- Software quality assurance requirements that should be required by contract,

- Provisions for staffing projects with the technical expertise required at all levels,

- References to standards/guidelines specifically written for software,

- Evaluation/corrective action procedures specifically developed for software quality assurance, and

- Methods of communication among all government personnel involved in software quality assurance for the project.

Once this objective has been attained, then the work of implementing software quality assurance practices throughout the software development process will be performed with greater facility.

4.3 RELATION OF SOFTWARE QUALITY ASSURANCE TO SOFTWARE DEVELOPMENT

Software development extends from the identification of the system requirements to product "buy-off" and subsequent in-field operation.

During the software development, software quality assurance provides assessments, evaluations, and reviews of the software products. Software quality assurance also conducts many of the actual software control functions. Some of the controls covered by software quality assurance consist of the following:

- Incorporation of software quality assurance into the overall software program planning,

- Preparation and evaluation of standards that guide the preparation of software documentation, design, code, validation and verification,

- Evaluation of the software design process and design products for conformance to requirements,

- Monitoring of the software design for compliance with design and performance requirements, adequacy of methods used, and positive evidence of compliance,

- Review of software test requirements, plans and procedures for compatibility and adequacy,

- Monitoring of software tests for conformance with procedures, and

- Implementation of a system for recording, reporting, and tracking software problems and for assuring the adequacy of corrective actions.

In light of the above criteria, the following subsections discuss the advantages of and problems associated with the changes requested regarding the relation of software quality assurance to software development. Again, the purpose is not to address each of these criteria at this time. Each change request is examined in order to determine areas where criteria are not being met and where improvements can be made.

4.3.1 Use Life Cycle Model In Planning

Authorities in the software field agree on the importance of a life cycle model in planning and implementing a software development program. Life cycle models are often graphic representations of all development activities; and, if structured correctly, work in conjunction with the management plan. A typical life cycle model will be divided into phases of software development and each phase partitioned into more specific functional activities. Input data, output data including documentation, and appropriate quality assurance activities will be specified. Use of a life cycle model will ensure that: milestones are established and goals are set by all project members; no activities are omitted; proper documentation is prepared on time; and a system of controls is defined to accomplish project objectives.

4.3.2 Integrate Software Quality Assurance Activities In Life Cycle Models

Graphic depictions of where software quality assurance activities "fit" into the software development process present a total picture to the software quality assurance personnel and aid them in preparing and channeling efforts, tools and techniques in the appropriate direction. Software quality assurance personnel working with such a model will review and evaluate the approach, the methods, the status, and the achievements during each software development stage. Performance of these activities during the proper stage could generate a list of problem areas requiring immediate solution. Assessment of problems and application of corrective action early in a project has proved to minimize the negative effects on cost and schedule performance involved with later error detection.

4.3.3 Address Software In Configuration Management Plans

In conjunction with life cycle development, configuration management identifies, baselines, controls, and reports

changes to software products. Configuration management plans
are logical extensions of overall management plans. Software
is a unique commodity and should be included as such in con-
figuration management plans. If this is accomplished early
in the acquisition process, needed changes will be discovered
and implemented. Costly errors that are discovered later in
software development will be minimal.

4.3.4 Provide for Government Enforcement of Contractor Configuration Management Plans

Although configuration management plans may vary from
contractor to contractor, the development of procedures for
maintaining software stability and controlling change should
be contractual requirements; and, therefore, subject to en-
forcement. If software quality assurance personnel are in-
volved in Request for Proposal preparation and Contract Award
negotiations, they could ensure that the configuration of
computer programs and all associated documents are controlled
by the identification and baselining of configurations.
Change control and accounting procedures to assure proper
implementation and visibility could be developed for software
changes.

4.3.5 Involve Software Quality Assurance Personnel In Baselining Activities

In the development of software life cycle plans and
models, the establishment of baselines is an integral part.
Establishing baselines in the system life cycle development
is done by the contractor subject to review and approval by
the government; however, software quality assurance personnel
can play an important role in evaluating baseline documents.
Baselines are references. On a life cycle model, each rep-
resents a point where the software system definition is
formally reviewed, agreed upon, and published as the new
reference.

System baseline documents are the tangible products of the system development process. They are the principal communications media within the contractor's organization and between the contractor and the acquisition agency. It is the purpose of the software quality assurance staff to ensure that the baseline documents provide structure for attaining and maintaining the visibility necessary to control change, properly audit the system to ensure integrity and provide all concerned with detailed information concerning the status of the system at any point in time.

4.3.6 Provide More Reviews

If software quality assurance activities are integrated with life cycle models and software development planning, areas where reviews are required will be evident. Every phase of software development should include adequate reviews. In expanding the quality assurance sections of guidance documents caution should be exercised in developing more reviews. There may be an adequate number of reviews, but the manner in which they are conducted may be inadequate.

Formal and informal reviews are required and are conducted in contracted software development projects. However, software quality assurance evaluators generally monitor contractor reviews. If software quality assurance requirements are specified by contract, the task of software quality assurance personnel is to ensure that requirements are fulfilled. This means they must conduct reviews and evaluations independent of contractor reviews. Independent reviews and evaluation tools developed and applied by software quality assurance staff may uncover errors overlooked by contractors. As has been emphasized, discovery of errors at the appropriate stage and application of corrective action will save the time and costs that later error detection will cause.

4.3.7 Problems Associated With Requested Changes Regarding the Relation of Software Quality Assurance to Software Development

The primary difficulty with regard to improving the relation of software quality assurance to software development is the planning effort. Resources will have to be dedicated to developing a model life cycle with software quality assurance activities integrated.

The participants in the development of model reviews, audits and documentation procedures should be specifically selected, based on the goal to be achieved and their ability to contribute to achieving that goal. Again decisions will have to be made with regard to the use of in-house personnel or outside consultants. The factors to be considered are essentially the same as those for consideration in making decisions on improving software quality assurance guidance documents; namely, the scope of work involved, the projected costs of the effort and the effects of both on ensuring an improved quality of software.

4.3.8 Summary

The development of quality software will most likely occur only if the controls necessary for assuring quality are planned and specified as requirements. Specification of requirements will enable the software quality assurance group to exert a more effective influence in the development of quality software. In order for this to occur it is necessary that:

- Software is addressed in contractor configuration management plans,

- Software quality assurance personnel are involved in evaluation of baseline documentation,

- Standards are developed that guide the preparation of software documentation, design, code, validation and verification,

- Standard checklists are developed for reviews, assessments and evaluations of software products,

- Developed standards are adaptable to specific contracts, and

- A system for recording, reporting and tracking software problems is implemented.

Once the software quality assurance guidance document is developed and life cycle development with integrated software quality assurance activities is structured, then communication methods, including specifications for documentation and documentation reviews, and requirements for maintaining records must be clearly defined.

4.4 COMMUNICATION METHODS AND MODEL DOCUMENTS

Most of the comments here are directed toward formal communications. Informal methods of communication are important and are effective, but are more loosely constructed. Many of the shortcomings in a software project can be traced in part to misunderstandings resulting from communication failures. By maintaining a clearly defined and coherent communication system, these problems can be reduced with positive effects on the software development project.

There are two essential methods to reduce communication failures. The first is to reduce, as much as possible, the number of communications required. This is accomplished by partitioning tasks and simplifying interfaces and interchanges. The second is to provide reliable, readily available communciation channels and mechanisms wherever needed.

In a software development project, review of documentation is the primary means of assessment and evaluation. Software offers no visibility except through its associated documentation. The quality of documentation is directly related to the quality of software. Superior documentation increases the probability of the quality of delivered software. Poor documentation decreases

the probability of quality of the delivered software. Hence, documentation is the primary form of communication between the developer, the software quality assurance staff and the end user.

For effective communication to occur it is essential that:

- The purpose of the communication be stated,

- The methods of communication be structured,

- All project staff be aware of the lines of communication and their particular responsibilities, and

- If possible, the time communication is required is specified.

In light of these criteria, the following subsections discuss the advantages of and problems associated with the changes requested for improvement of communicaitons. Each change request is examined in order to determine areas where criteria are not being met and where improvements can be made.

4.4.1 Structure the Communication System

A communication system is a necessary means of linking the various parts of a large organization. By formally defining methods and channels of communication, confusion is minimized. Distortion due to mishandling of information is reduced. A good communicaiton system can ensure that the important information is transmitted and the unimportant is discarded. If the person at the end of the communication channel receives only information which he knows is important, that information will receive proper attention and not stagnate in a bottomless pile. This is time efficient for all involved.

4.4.2 Provide Definite Regulations and Guidelines

Guidelines and regulations are essential to ensure a reliable and uniform communication system. If the proper guidelines are established and followed, lines of communication will be determined and transmissions will be released on time, and to the proper people.

Documentation requirements, design reviews and configuration control are integrally related to communication. Specific formats for documents should be available prior to initiation of the attendant development phase if a good product is expected. Considerable manpower can be saved if the engineers know exactly what they must produce in the way of documentation and exactly how and when to produce it. If documentation is planned, associated reviews and audits should discover errors early on in each phase, provide for correction, save time and costs and allow a project to remain on schedule. Audits should be conducted as official audits to evaluate conformance of prepared documentation to contractual requirements.

4.4.3 Emphasize Coordination Among All Project Staff

The importance of establishing lines of communication among staff members has been emphasized. Each participant must be aware of each other participant's responsibilities and who is to be contacted when necessary. The problem of overlooking a staff member, though unintentional, could occur and a standardized communication system will remedy this. Staff support in management-related matters is essential. The management process, like all others, is interactive. The results of that interaction depend on the awareness and cooperation of all parties involved. If management has not clearly defined the functions to be performed, this important interaction cannot take place.

In establishing clearly defined channels, experts can be identified to whom others can turn for assistance in solving problems. This is a factor relative to informal rather than formal communication. If a staff member has a problem and knows exactly whom to contact, time would be saved and fewer people would be involved. Although sound in theory, this is difficult to accomplish. Identification of experts requires thorough familiarity with the organization and its resources.

4.4.4 Problems Associated With Requested Changes For Improvement of Communication Methods and Model Documents

Project managers must maintain a high degree of awareness of the status of all project matters. No matter how complete and concise a project plan may be, there is a need for adjustments and explicit decisions every day. If the communication system is too rigidly structured, some things may be compromised; for example, the flexibility needed to meet emergencies.

There is a problem associated with too many regulations and guidelines. If staff people are flooded with directives, there is confusion regarding which to follow and the tendency may be to ignore the directives and improvise.

Standardizing the communication system can be time-consuming. In planning and implementing any new policies and procedures, unforeseen problems may surface. The tendency may be to dispense with the new and revert to the former ways of operating. An initial period of adjustment is needed before the effects of a smoothly running communication system are realized.

4.4.5 Summary

In establishing a communication system, it is important to provide for both formal and informal methods. Formal communication emphasizes the dissemination of information. Usually, these are written. Informal communication refers to interpersonal communications between two or more people; for example, face-to-face meetings or telephone conversations. Both types of communication are important and both can be planned.

In establishing a formal communication system it is important to determine:

- The purpose of the communication;

- The sender and the recipient;

- the communication media;
- Follow-up action, if any;
- Records to be maintained, if any; and
- Timeliness of communications.

If these determinations are made before a project begins, policies and procedures will be facilitated for handling major issues and problems. The informal communications that occur on a routine daily basis will provide for adjustments in minor areas.

What must be emphasized is that no guidance documents, life cycle development plan nor communication system, no matter how well planned, will, of themselves, ensure the quality of software. The key factor for development and implementation is software quality assurance personnel who possess the required expertise. The necessity of providing the required software oriented skills to the software quality assurance staff is imperative.

4.5 TRAINING AND STAFFING

Throughout the interview sessions and questionnaire responses, there was overwhelming agreement among respondents on the issue of training. In every area of questioning, respondents emphasized this issue. Personnel felt greater involvement on the part of software quality assurance personnel, both on the management level and the operations level, will be of little benefit: (1) If training is not provided to those already in government service who are making efforts to perform their functions adequately, and (2) If personnel with training in software areas are not hired. It is evident that software quality assurance personnel are conscientious regarding their work and are aware that education is essential if the quality of software is to improve.

The need for training cannot be over-emphasized. If software quality assurance personnel do not have the technical exper-

tise to ensure that software quality assurance requirements are met in each of the successive baselining evaluations, the resulting effects on the software product may be devastating. Despite the fact that planning the system development and establishing baselines are not functions of the software quality assurance staff, knowledge of these software areas is essential for effective evaluation to be performed. It is unreasonable to expect evaluators to assess performance if their technical expertise is not on the level of their counterparts on the contractor's staff. Again, survey respondents themselves have addressed this issue throughout all areas as one needing serious consideration.

The following subsections discuss the advantages of and problems associated with the changes requested for improvement of training and staffing. Each change request is examined in order to determine where improvements can be made.

4.5.1 Make Training Available to More Personnel

The most important resource in developing and implementing a software quality assurance plan is skilled personnel. Managers and operations personnel with software oriented skills have the capability to specify requirements, independently assess a contractor's plans for fulfilling contractual requirements and to evaluate whether or not the plan is being followed and implemented successfully. Through unforeseen circumstances, requirements may change, but by following a structured and concise plan, skilled managers and operations personnel will be able to make adjustments quickly and reduce loss of time and added costs.

Again, software is an intangible commodity with its own particular problems and methods of solution. Personnel familiar with these areas through past experience and/or through training will anticipate occurrences, where possible

and offer technical advice when unforeseen situations arise.

Since an overwhelming number of respondents expressed the need for training in the area of software engineering, it must be assumed that managers and operations personnel are experiencing difficulty in assuring the quality of software because they lack technical expertise or they are not current with the state-of-the-art. Certainly, those involved on a daily basis with software quality assurance should be able to interact with contractor personnel whom they are monitoring. If such is the case, the level of the quality of software should increase.

4.5.2 Develop Structured Training Courses

Software development in industry and government is growing at an incredible rate. The number of people needed in work requiring direct participation in software development activities is increasing and, therefore, the opportunities for trained software professionals are expanding. Enlightened managers now recognize the importance and the risks associated with software development, and few projects of substantial size are successfully accomplished without explicit planning, control, and a high degree of visibility

Unfortunately, software projects that meet schedule, cost, and performance objectives are still the exception and not the rule. Some of the most common complaints are:

- Delivered Software is far behind schedule, costs more than budgeted, and performs inadequately;

- Software is constructed and documented so poorly that it is almost impossible to maintain and enhance at reasonable costs; and

- Software is unreliable and requires constant maintenance to correct errors discovered during operation.

The explanation of the industry's poor record does not lie in the fundamental difficulty of the work. The actual difficulty has been in matching the appropriate resources to the problem. This, in turn, derives from two factors:

Inability to identify and appreciate all aspects of the problem; and

Poor packaging of the resources, i.e., the required talents are distributed over a large group of individuals.

Software engineering and management education can serve to alleviate the first of these factors by exposing personnel to the full scope of the software development environment, and the second by preparing personnel with a better cross section of abilities with which to operate in that environment.

4.5.3 Establish Certification Programs

If the government is unable to compete with industry in hiring software managers, certification programs to train software specialists can be an alternative solution. Certification programs have several advantages. They will be geared to Government systems and acquisition procedures and provide standard training. They will provide a level of depth at the technical level that will give the software quality assurance monitors the expertise and confidence necessary to deal with contractor personnel. If the government takes a lead role in recognizing that computer software is a commodity as is electronics, aeronautics, etc., and establishes certification programs toward that end, contractors' confidence in government software quality assurance performance will be enhanced. The contractors' own software quality assurance plans will reflect the added pressure to provide quality software within schedule and

cost parameters. Finally, certification programs will encourage and facilitate further in-depth training and emphasis in this area.

4.5.4 Provide Orientation Instruction

Orientation instruction is necessary regardless of the amount of training or technical expertise obtained by personnel. Orientation is specific to a facility and the program. Familiarization with contractors' organizations, methodologies and lines of communication will enable the software quality assurance personnel to plan procedures that can be accomplished efficiently. Orientation instruction will provide personnel with a brief description of the system, the specifications applicable to the system, and the work already accomplished. For personnel new to Government acquisition procedures, instruction in the role of the software quality assurance personnel in software acquisition management, and briefings on related military documents will provide the parameters within which software skills are utilized and again will save time that may be wasted in learning on an "as needed" basis.

4.5.5 Problems Associated With Requested Changes Concerning Training and Staffing

Software quality assurance personnel are sometimes assigned to projects requiring specialized skills they do not have. During the course of the project, they may request and may be provided some training to enable them to perform their tasks. However, the project continues and by the time training is completed, it is too late to be applied. The best time to receive training is not on an "as needed" basis, even though this is far more preferable than not to receive any training at all.

Technological advances in software development are resulting in improved automated tools for design, coding

and testing. Thi. is creating the need for software quality assurance personnel with more specialized skills for reviewing and evaluating products generated. Training in the basic principles of software engineering supplemented by specialized software quality assurance skills should be in place already. In developing plans for training, consideration should be given to training software quality assurance personnel in the performance of specific activities during specific life cycle phases. Specialization may directly affect the quality of software.

Acquiring skilled software quality assurance personnel is a particular problem for the Government. Due to present job classifications, the Government is unable to compete with the private sector for scarce resources. To further complicate the matter, personnel trained in software quality assurance often leave government service for private industry. This could be repeated upon hiring and training new personnel with the accompanying loss of time and money. However, the organizational profile developed during this study has revealed that many of the CAO personnel are dedicated career employees. Training to retread these government personnel who are committed to government service should result in less attrition. This could prove to be an effective stop-gap measure while a longer range solution is being planned.

4.5.6 Summary

In order for software quality assurance personnel to meet the increasing advances of software technology and influence the quality of software some provisions on training must be implemented. Training should cover the entire acquisition from preparation of Requests for Proposals through the software development life cycle. The most important attribute implied by the term "software quality assurance personnel" is that of a problem discoverer. Through educa-

tion in software management and software engineering orien-
ted courses the software quality assurance staff will be
able to:

- Assist in determining the needs of the buying
  activity;

- Evaluate the general approach to the system
  development;

- Analyze requirements to determine and report
  conflicts;

- Evaluate a software quality assurance plan
  against constraints imposed by cost, schedule,
  and operating environment;

- Track corrective action procedures;

- Communicate effectively with supervisors, subor-
  dinates, contractor staff, and counterparts;

- Interact effectively with others involved in
  other disciplines (for example, hardware and
  budget) who are associated with the project.

The greatest sense of purpose for software quality
assurance personnel will come from the knowledge that the
headquarters: (1) Is aware of the importance of software
quality assurance, (2) Is cognizant that staff people have
the desire to perform their functions as expertly as pos-
sible and are willing to be trained to that end, and (3) Is
willing to make the necessary provisions. Confidence in
one's ability and appreciation of the significance of one's
professional performance can often overcome the frustrations
surrounding daily routine.

SECTION V

DETAILED AREAS FOR IMPROVEMENT

5.1 OVERVIEW

Most respondents stated that the original requirements for software quality assurance are often de-emphasized during the software development projects. When cost overruns are anticipated there is the tendency to "cut corners" in the area of software quality assurance. The software quality assurance management plan and life cycle model plan must be well structured; software quality assurance activities must be appropriately integrated into the life cycle plan; software quality assurance tools and techniques must be independently planned and used; and lines of communication must be firmly established. If software quality assurance requirements are specified in RFP's, and plans are developed for fulfilling these requirements, the selection of software quality assurance as the area for de-emphasis will be made more difficult if not impossible. Cost overruns should be greatly reduced and the need to "cut corners" will be minimized.

5.2 CRITICAL AREAS FOR IMPROVEMENT

As a result of the analysis of current software quality assurance practices and the evaluation of requested changes, four areas for improvement are determined:

(1) Software Quality Assurance Guidance Documents,

(2) The Relation of Software Quality Assurance to Software Development,

(3) Communication Methods and Model Documentation, and

(4) Training and Staffing.

In the following subsections, specific suggestions for improvement are detailed. In most cases, areas for improvement encompass all organizations, namely, the Defense Logistics Agency, the Electronic Systems Division and The Air Force Contract Management Division. Where a particular improvement is applicable to a specific organization, this has been so specified.

5.3 AREAS FOR IMPROVEMENT IN SOFTWARE QUALITY ASSURANCE GUIDANCE DOCUMENTS

If the quality of software is to reflect improvement several concepts must be recognized and accepted. First, although software development and software quality assurance are considered to be separate unique disciplines, they must be considered as interdependent when developing plans and procedures.

Second, a software quality assurance program can be broken into three phases: (1) planning, (2) development, and (3) implementation. While the boundaries of these three phases are not distinct, it is necessary to accomplish all three to have an effective software quality assurance program. The major product of this first phase is the software quality assurance management plan. Phases two and three are discussed in subsections 5.4 and 5.5.

5.3.1 Criteria for Improvement

In order to develop a software quality assurance management plan, guidance documents must specify guidelines for all the major elements of a plan. With the aid of these guidelines, software quality assurance management plans can be developed that are specific to a project. The major elements that should be included in a software quality assurance guidance document are:

- Precontract planning to incorporate software quality assurance provisions into request for proposals;

- Definition of software quality assurance tasks and methods;

- Division of organizational responsibilities for the software quality assurance tasks;

- Development of the basic software quality assurance communication structure; and

- Selection of personnel for carrying out all tasks.

5.3.2 Areas for Improvement

In the Defense Logistics Agency, the primary guidance document for software quality assurance is DLAM 8200.1, Section IX, Part 15, Procurement Quality Assurance for Computer Software. Although this document addresses some of the basic elements of a software quality assurance management plan, procedures for implementation are heavily hardware oriented. For example, methods for performing Procedures Review and Procedures Evaluation are referenced to those areas in the manual that were developed for hardware quality assurance.

Within the Electronic Systems Division, the contractor's Computer Program Development Plan in conjunction with AFR 800-14, Acquisition and Support Procedures for Computer Resources in Systems, and MIL-STD-483, Configuration Management Practices for Systems, Equipment, Munitions, and Computer Programs, are the primary guidance documents for software development. There is no document solely for software quality assurance.

The Electronic Systems Division's Software Acquisition Management Guidebooks, in particular, ESD-TR-77-225, Software Quality Assurance are excellent plans, yet, little or no mention was made of them by survey respondents. This may be

because they are guidebooks and not mandatory regulations. Wider use of these documents with some modifications is encouraged.

In the Air Force Contract Management Division, the primary guidance document for software quality assurance is AFCMDR 74-1, Procurement Quality Assurance Program, Chapter 15. Chapter 15 does deal directly with software quality assurance, but references to other guidelines that are hardware oriented are used extensively. Expansion of all documents dealing with software quality assurance will present a more cohesive structure for evaluators to follow and will provide the tools necessary for the accomplishment of the plan. AFCMDR 800-1, Contract Management Engineering, and AFCMDP 800-2, Contract Management Engineering Guide, provide guidance for performing contract management engineering functions in support of the Air Force Contract Management Division (AFCMD) mission.

AFCMDR 178-1, Contractor Management System Evaluation Program, is a well organized, structured method for evaluating contractor plans. However, there is no section dealing with software quality assurance. Adding this section will provide software quality assurance personnel with detailed questions specific to software which would likely be omitted if reliance is placed solely on the Quality Assurance Section.

After a review of all guidance documents for the major elements of a software quality assurance management plan the following areas for improvement are determined for the Defense Logistics Agency, the Electronic Systems Division and the Air Force Contract Management Division:

● Greater involvement of software quality assurance personnel in early acquisition phases;

- Specification of division of functions in Letters of Delegation and Memoranda of Agreement;

- Expansion of regulations to detail government software quality assurance procedures for monitoring contractors; and

- Development of review and evaluation procedures specifically software quality assurance oriented.

5.3.2.1 Greater Involvement of Software Quality Assurance Personnel in Early Acquisition Phases

Involvement of software quality assurance personnel early in the acquisition cycle is imperative. Based on their past experiences, software quality assurance personnel are aware of areas where software quality assurance was de-emphasized during software development. If they participate in request for proposal preparation, they will recommend incorporation of software quality assurance requirements. As a result, contractors will submit clearly defined plans and procedures. At the time of contract award negotiations, clear definitions of what is expected from the contractor's and the government's quality assurance programs will be established. Later problems causing cost overruns and schedule delays will be minimal.

The Electronic Systems Division's Software Acquisition Management Guidebooks detail the procedures of RFP preparation, proposal evaluations and contract award negotiations. The inclusion of software quality assurance personnel as participants in these activities is not so specified. Software quality assurance participation would require a minimum effort and yield significant benefits.

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In summary, incorporation of a pre-planning section in the software quality assurance guidance documents will result in the following benefits:

- Specifications on software quality assurance requirements in requests for proposals and contracts,

- Inclusion of software quality assurance requirements in requests for proposals and contracts,

- Reduction of future problems through utilization of past experiences,

- Reduction of delays in schedule performance, and

- Reduction in costs.

5.3.2.2 Clear Division of Functions

Where unique quality assurance actions to be performed by the Contract Administration Office are specified through quality assurance Letters of Delegation or Memoranda of Agreement, respondents were able to supply very little data. Respondents seemed to have little knowledge of how division of functions are negotiated. However, respondents stated that schedule slippages, cost overruns and a de-emphasis of software quality assurance requirements occur, generally, because of poor planning and lack of government technical expertise.

Regulations governing the division of functions do exist; therefore, a breakdown in communications can be assumed to exist. These functions are delegated by the Program Office. Negotiations ensure where resources are available to perform special tasks. Only those respondents dealing with the everyday activities of software

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quality assurance are aware of available resources. For negotiations to be effective, input from the software quality a surance staff, both at management and operations levels, is essential. This will result in developing Memoranda of Agreement with more detailed specifications regarding the provisions on software. Memoranda of Agreement and Letters of Delegation that are written early in the acquisition process with input from the above mentioned levels will clearly define responsibilities and communicate these responsibilities to all concerned.

In summary, Letters of Delegation and Memoranda of Agreement written based on communication between the Program Office and Contract Administration Office will:

- Specify provisions on software,

- Determine availablity of technical resources,

- Assign tasks as they will occur during the software life cycle phases, and

- Establish lines of communication.

5.3.2.3 Expansion of Regulations to Detail Software Quality Assurance Procedures for Monitoring Contractors

Regulations and standards referenced in existing software quality assurance guidance documents are written in general terms. For example, MIL-S-52799A, Software Quality Assurance Program Requirements, lists contractor plans that the software quality assurance personnel must identify as existing and consistent with contractual requirements, but there are no details provided to ensure that the requirements are adequate.

In some cases, references to other regulations and standards are extensive and cross referencing can be considerably time consuming. Again, many regulations and standards are based on procedures developed for hardware quality assurance.

Expansion of software quality assurance guidance documents should include consolidation of relevant information from all necessary regulations into one general document. Based on this general plan, plans tailor made for specific contracts can be formulated without repetition or standard requirements. Regulations for software quality assurance should be unique regulations geared specifically for software as should the software quality assurance guidance documents.

5.3.2.4 Development of Review and Evaluation Procedures that are Specifically Software Quality Assurance Oriented

References to hardware oriented procedures for evaluating software quality assurance should be eliminated from software quality assurance guidance documents. There are few similarities between the tangible hardware equipment and the software products. There are also few similarities between evaluating hardware and evaluating software products. Again, software quality assurance evaluation procedures should be unique procedures.

5.4 AREAS FOR IMPROVEMENT IN THE RELATION OF SOFTWARE QUALITY ASSURANCE TO SOFTWARE DEVELOPMENT

Integrating software quality assurance activities with the software development activities entails setting up the working relationship between functional organizations, and documenting these interfaces with operating procedures and instructions.

A system of assesments, evaluations and reviews, both formal
and informal, are planned for specific milestones, baseline docu-
mentation and other documentation required in the development
process.

5.4.1 Criteria for Improvement

Specifically, some of the major responsibilities of
the software quality assurance group consisting of program
office and CAO representatives are:

- Ensuring that sound software development practices are
  followed throughout the software development life cycle,

- Ensuring that software quality control procedures
  required by contract are planned by the contractor,

- Developing tools and techniques for monitoring con-
  tractor reviews and audits, and

- Reviewing all acceptance test plans and procedures.

In the development of monitoring and evaluation tools
and techniques, software quality assurance personnel should
develop standard independent tools that can be adapted to
specific based contract requirements and contractor's plans.
Reliance should not be placed solely on contractor's results
of reviews.

5.4.2 Areas For Improvement

Based on a review of life cycle models, software
development phases and related software quality assurance
activities, the following areas of improvement were determined
for the Defense Logistics Agency, the Electronic Systems
Division and the Air Force Contract Management Division:

- Integration of software quality assurance activities
  into the total life cycle development model,

- Participation in establishing and evaluating baselines,

- Development of standard formats for writing documents,

- Development of specific tools, techniques and methodologies for monitoring and evaluating contractor software quality assurance plans and procedures that are required by contract.

5.4.2.1 Integration of Software Quality Assurance Activities into Life Cycle Development Model

Since DLA is in the process of revising its life cycle model, comments concerning the present model are limited. DLAM 8200.1, Procurement Quality Assurance exhibits charts of quality control documents and the typical sequence of events for computer software programs with quality assurance concerns specified. Incorporation of the data from these charts into the revised life cycle model would create a single reference point which would facilitate planning. Modifications could be made on a contract basis and special requirements and activities could be integrated with minimum difficulty.

Electronic Systems Division's Software Acquisition Management Guidebook Series forms a solid working basis from which to develop a life cycle model with integrated quality assurance activities. The guidebooks develop in great detail the quality assurance activities that are to be performed during each phase, corresponding documentation to be reviewed and documentation to be completed. What remains is to highlight and consolidate in one graphic depiction for each life cycle phase, the major software quality assurance activities performed, and standard documentation involved. This type of model will facilitate planning. With this as a basis, modifications needed to adhere to special

requirements of particular contracts can be made with
minimum difficulty.

The Air Force Contract Management Division's
Procurement Quality Assurance Program, AFCMDR 74-1,
Chapter 15, illustrates several charts of life cycle
model phases with contractor requirements and products
specified. AFCMDR 800-1, Contract Management Engineer-
ing and AFCMDP 800-2, Contract Management Engineering
Guide also detail the breakdown of life cycle phases
and the activities to be performed by AFCMD Engineer-
ing. These documents form a solid basis where quality
assurance activities can be integrated without the
necessity of a major revision.

Integrating quality assurance activities into
a life cycle model can be accomplished with a minimum
of effort by the Defense Logistics Agency, the Elec-
tronic Systems Division and the Air Force Contract
Management Division. Since basic data exists in docu-
mentation of these three organizations regarding soft-
ware quality assurance functions, all that is required
is to select software quality assurance functions and
map them into the appropriate phases of the life cycle
model to present an organized visual representation of
the software development process.

5.4.2.2 Participation in Establishing and Evaluating
         Baselines

A baseline is a reference point which estab-
lishes a basis of understanding among all project staff.
Software quality assurance personnel within the Defense
Logistics Agency, the Electronic Systems Division and
the Air Force Contract Management Division do work with
baselines. The Electronic Systems Division sometimes
participates in the development of baselines. The
Defense Logistics Agency and the Air Force Contract

Management Division do not. Not only should software quality assurance personnel use baselines as reference points but they should be involved in their development. At the very least, they should evaluate baseline documentation.

According to MIL-STD-483 baselines are defined as:

- Functional Baseline - the initial approved functional configuration identification;

- Allocated Baseline - the initial approved allocated configuration identification; and

- Product Baseline - The initial, approved or conditionally approved product configuration identification.

Software quality assurance personnel should evaluate at a minimum:

- Functional baseline documents to determine if the system will meet the requirements;

- Allocated baseline documents to determine if the functions to be performed by the software components are complete and ready for use in building and integrating the system; and

- Product baseline documents to ensure that corrections to deficiencies found in the testing of the product baseline have been documented and contractual requirements are being met.

Baselines are the principal communications media between the developer, the Contract Administration Offices and the acquisition activity. To exclude software quality assurance from the evaluation of baseline documentation is to exclude the essential

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control system and, therefore, excludes or at least diminishes considerably the probability of quality software.

5.4.2.3 Development of Model Documents

Quality assurance as a discipline is commonly invoked throughout governmental and industrial organizations with reasonable standardization when applied to systems comprised only of hardware. But there is enormous variation in thinking and practice when the quality assurance discipline is invoked for software development or for a system containing software components. Software, as a form of information, cannot be standardized; only structures for defining and documenting software can be standardized. If the structures for all software documentation have been clearly defined from the early stages of system acquisition, specific formats for documents will be available prior to initiation of the attendant development phase. Considerable manpower can be saved if the engineers know exactly what they must produce in the way of documentation and exactly how and when.

Although Data Item Descriptions (DIDs) and Contract Data Requirements Lists (CDRLs) do define the requirements for documentation, respondents noted that documents are sometimes poorly written and very often, behind schedule. Documents may contain what they are supposed to contain and still be inferior. Preparation of model document packages can range from simple outlines structuring the contents into some logical order, to preparation of complete samples of each major type of document that is generally produced.

If specific formats for superior documentation are standardized and required, and an initial

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period of implementation and enforcement is allowed in order to work out problems, documentation from contractors will become more uniform. In fact, it will be easier for them to prepare. The reviews performed by software quality assurance will be performed with greater facility and the quality of software will improve within schedule and cost constraints. Rigidity is not being suggested here. What is being suggested is a basic format which will allow tailoring for specific project requirements.

5.4.2.4 Development of Tools, Techniques and Methodologies

Special tools, techniques, and methodologies are planned, controlled, and applied to support software quality assurance objectives and assist in software verification. On the assumption that the software life cycle model has been planned and constructed as previously discussed, reviews and audits are then seen as an integral part. Due to the complexity and diversity of software projects, it is not possible nor reasonable to suggest which particular tools to use. However, some comments on tool development are appropriate.

The government's primary tools for monitoring contractors are checklists for assessing contractor documentation. If documentation is planned, associated reviews and audits will discover errors early on in each phase, provide for correction, save time and costs and allow a project to remain on schedule. Audits will be conducted as official audits to evaluate conformance of prepared documentation to contractual requirements. Once the requirements of each phase have been specified with its corresponding reviews, audits and documentation,

checklists for assessment of quality can and should be tailor made to the contract.

Checklists should be independently developed by software quality assurance personnel based on contractor Computer Program Development Plans, and contract requirements. If requirements for a software configuration management plan have been specified, checklists should be constructed based on those requirements. It is possible to construct a standard checklist which includes the elements of a good software configuration management plan. This standard checklist can then be used to evaluate contractors' plans for compliance with contract requirements, procedures for implementation and, most importantly, the adequacy of their procedures.
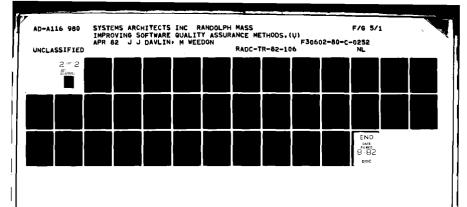
According to the Electronic Systems Division, checklists are modeled after the DIDs and standards. If this is done according to the above principles and are adaptable to all projects, then the software quality assurance staff's tasks of monitoring and evaluating should be less tedious.

SAI was able to obtain very few checklists, primarily due to the proprietary data involved, therefore, a checklist evaluation was not possible. However, many respondents indicated that they do use checklists and complete them based on "what the contractor says has been done". The criteria is the good rapport developed between the contractor and government software quality assurance personnel.

Witnessing of software testing should follow the same plan. Requirements should be documented and checklists developed from the requirements. Software quality assurance personnel should know the test sequence, the test input data, the data base and the

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software configuration in order to identify irregularities in their evaluations. Observations of the test itself and evaluation of the test output data constitute the basis on which it is determined if the test objectives have been met, the pertinent requirements verified and the acceptance criteria satisfied. Government software quality assurance evaluators should be able to evaluate a test report in light of the objectives of the test and note any anomalies. Disciplined control of the testing effort should be maintained by emphasizing comprehensive and precise definition of test plans, and evaluation of test achievement against the test plan at periodic checkpoints.

For complex programs, automated tools are becoming a necessity in order to permit adherence to system requirements. Use of automated tools may make the software quality assurance evaluator's task less tedious but he or she will need to be educated as to their purpose and applicability to specific projects. They will need to be aware of the appropriateness of the tool in the life cycle development phase, what the output should indicate, and how it interacts with the activities of other phases.

Reviewing, monitoring and witnessing of contractor's quality assurance procedures are satisfactory if the technical expertise exists to perform these activities. Increased technical skill will allow software quality assurance personnel to participate actively in these functions. The purpose is not to dictate to the contractor how to perform tasks, but to provide the software quality assurance evaluator with the basic understanding of the techniques used by the contractor. Checklists can then be completed from a technical evaluation rather than, again,

simply determining that a contractor has or has not addressed a quality requirement.

5.5 AREAS FOR IMPROVEMENT IN COMMUNICATION METHODS AND MODEL DOCUMENTS

Software quality assurance plans, no matter how well structured, will fall short of their objectives if the system of communication is not well planned. In order for any program to achieve its objectives, all project personnel must be aware of the objectives, the procedures to be used to obtain the objectives, and the methods and lines of communications to be used. Communication is defined as the transmission of meaning to others. Formal communication emphasizes the dissemination of information and informal communication consists of exchanges between two or more people. Both are necessary and though the latter is more loosely constructed, some guidelines are necessary to govern its use.

5.5.1 Criteria for Improvement

The following guides are presented to aid in developing effective communication:

- Determine the purpose of the communication;

- Develop a system of communication flow to be followed during project implementation;

- Determine appropriate standards and regulations;

- Ensure that all project personnel are made aware of the communication system.

The communication system need not be rigid. It should maintain a degree of flexibility, yet ensure that all personnel send and receive information relevant to their functions.

5.5.2 Areas for Improvement

Based on the criteria for improvement of communication methods, the following areas of improvement are determined for the Defense Logistics Agency, the Eletronic Systems

Division and the Air Force Contract Management Division:

- Determine the formal and informal methods of communication;

- Determine the flow of communication;

- Improve regulations and specifications that regulate communication methods; and

- Ensure that all project personnel receive information that affects their functions.

5.5.2.1 Determine Formal and Informal Methods of Communication

Letters, memos and reports that are to be a matter of record should be planned before the start of a project. The subject of these types of communication, for example, requests for changes, corrective action reports, performance assessments, acceptance reports, etc., should be formatted and prepared for use. The exact information that is to be included should be determined in order that uniformity be preserved.

Board meetings and panel discussions should also be planned before the project begins. The purpose should be clearly stated and the frequency determined. If one or more of the above mentioned reports is the subject of the meeting, all participants should be informed. If software quality assurance matters are affected then software quality assurance personnel should participate. This is not always the case according to respondents.

Most respondents stated that informal methods of communication (for example, telephoning for advice or assistance) are adequate and are effective. In establishing a communication system, this should not be lost.

5.5.2.2 Determine the Flow of Communication

A common complaint among respondents was that decisio.s are made concerning software quality assurance and software quality assurance personnel are not informed. Again, it should be a matter of record as to who should receive pertinent information and a distribution system should be established. If all project personnel have a list of all other project staff, there will be less opportunity for a staff member to be omitted in the distribution. If tasks have been specifically delegated, managers will direct their communications to the appropriate staff members, and staff members will submit reports to all who should receive them. A tracking system is relatively easy to establish, saves time, and avoids the frustrations involved in not receiving communications.

5.5.2.3 Improve Regulations and Specifications

Another common complaint from respondents was that software quality assurance personnel are not made aware of decisions made and tasks delegated through Memoranda of Agreement and Letters of Delegation. Regulations detailing the writing of MOAs/LODs should emphasize coordination between the Program Office and the software quality assurance staff before decisions are finalized. This necessitates that specific provisions on software be included. When modifications are necessary, renegotiations between the Program Office and software quality assurance staff are necessary to ensure that software quality assurance is not de-emphasized and new tasks assigned fall within the available technical expertise or can be acquired easily and quickly.

5.5.2.4 Orient Project Personnel to Communication System

In order that all project personnel be made aware of the communication system, a period of orientation is required. Regulations should specify the basic elements to be included in a communication system. However, each organization and project must apply regulations in a manner peculiar to its own structure and needs. New personnel must be made aware of the communication distribution system, the types of records to be maintained, standard forms required, and special formats to be followed. Points of contact can be established for those occasions when special technical assistance is needed. If the existing communication system is re-structured for improvement then all personnel will require reorientation. In restructuring the communication system it is important to allow for a period of adjustment.

5.6 TRAINING AND STAFFING

As has been stated, no software quality assurance management plan, no software development plan and no communication system however well planned and constructed will by itself assure the quality of software. The key factor is professionally trained personnel who are convinced of the vital importance of software quality assurance and its place in software development.

5.6.1 Criteria for Improvement

Performing software quality assurance is almost impossible without knowledge of software and its developmental processes. In order for software quality assurance personnel to perform their functions expertly and efficiently they must have the technical capability to:

- Understand software requirements, design, code and test procedures,

- Interact with contractor software quality assurance staff and software engineers, and

- Independently evaluate the contractor's plans for assuring the quality of software.

Software quality assurance managers must be aware of the required technilogy and possess the capabilities and skills necessary to:

- Manage personnel on various levels, and

- Maintain communication flow as planned.

In addition software quality assurance personnel must have the ability to make value judgments in unforeseen circumstances requiring immediate attention. They must preserve a strict control over plans that have been rigidly organized, yet be knowledgeable enough to determine where flexible decisions are warranted and be prepared to make them. This requires a firm foundation in the principles of management and in the software development process.

5.6.2 Areas for Improvement

The Defense Logistics Agency, the Electronic Systems Division and the Air Force Contract Management Division have personnel who have been exposed to some software courses. However, these appear to have been obtained on an as needed basis and in isolated situations. To assign personnel to a project and then provide training is cost ineffective. Projects continue and training received may be too late to affect the quality of the software being developed. The following areas for improvement in training and staffing are determined for the Defense Logistics Agency, the Electronic Systems Division and the Air Force Contract Management Division.

Personnel must be trained in a structured manner in the following skills;

- Management of software quality assurance projects;

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- Software development processes with software quality assurance procedures integrated;

- Use of software development tools and techniques;

- Procedures for developing software quality assurance checklists.

In addition, personnel assigned to projects should receive orientation regarding:

- Organizational responsibilities and operations within the Defense Logistics Agency, the Electronic Systems Division and the Air Force Contract Management Division;

- Contractors' facilities and methods of operations;

- Personnel responsibilities; and

- Lines of communication.

SECTION VI

RECOMMENDATIONS

6.1 OVERVIEW

Identifying those Areas for Improvement in Section V with
the greatest impact on quality software, SAI recommends changes
in four areas: (1) Government Software Quality Assurance Guidance
Documents, (2) The Relation of Software Quality Assurance to Soft-
ware Development, (3) Communication Methods and Model Documents,
and (4) Training and Staffing. Improvements in tools, techniques
and communication methods are predicated upon software quality
assurance guidance documents that recognize the development of
software as distinct from that of hardware. This means that re-
quirements are determined specifically for software and that the
government software quality assurance organizations and procedures
are developed around ensuring the accomplishment of these require-
ments.

Life cycle model planning is the foundation for the system
design whereby the best methods to attain the end quality product
are determined. "Best methods" and "quality" are the key words.
Quality software cannot be attained unless the methods of imple-
mentation are reviewed, assessed and corrected where necessary at
every step in each phase of the software development process.

Finally, no software quality assurance and software develop-
ment management plan will by themselves cause the quality of soft-
ware to increase. The most critical factor is personnel who have
the technical expertise to evaluate software requirements, develop
tools and techniques to review and assess compliance at the various
milestones, and recommend changes with adequate justification.
Computer technology is constantly changing and advancing and
provision must be made to update personnel in the state-of-the-art.
Continual training is essential, both for those personnel who have
a computer science background and those who do not. A Training
Course Outline designed to cover the major topics of software

quality assurance for Air Force/Electronic Systems Division contracts has been developed and submitted by Systems Architects, Inc.

It should be noted that planning for changes and implementation may result in increased costs in the beginning. But as these changes become a matter of accepted routine, as contractors become accustomed to project demands and begin to address them in their original plans, and when personnel become familiar with new procedures, a decrease in costs should occur and an improved quality of software should result.

Based on the analysis of current software quality assurance practices (Section III), the evaluation of change results (Section IV), and the detailed evaluation of areas for improvement (Section V), recommendations are provided for improvements in the above mentioned four major areas. The following subsections present:

- General recommendations applicable to all organizations,

- Specific recommendations that may be applicable to a particular organization,

- Benefits to be expected from implementation of recommendations, and

- Alternative recommendations, if implementation of specific recommendations is not immediately feasible.

Implementation of recommendations will lead to an increase in the quality of software if the cooperation of all personnel is encouraged and initial periods of adjustment are allowed.

6.2 RECOMMENDATIONS FOR THE IMPROVEMENT OF SOFTWARE QUALITY ASSURANCE GUIDANCE DOCUMENTS

If the quality of software is to improve, greater emphasis must be placed on software quality assurance as a separate discipline. Quality software cannot be attained by following hardware oriented plans and procedures. A software quality assurance guidance document should contain the following elements:

- Provision for clear division of responsibilities between the Program Office and the Contract Administration Office and within each organization,

- References to appropriate standards and regulations,

- Basic software quality assurance requirements to be specified in contracts,

- Evaluation and corrective action procedures specifically developed for software quality assurance, and

- Provisions for developing communications methods and responsibilities.

6.2.1 General Recommendations

Before any improvements in software quality assurance guidance documents can be effective, each organization must insist on the following:

(1) Software quality assurance requirements should be specified in request for proposals and resulting contracts.

(2) Software quality assurance personnel should participate in request for proposal preparation, review of proposals and contract award negotiations.

(3) Software quality assurance should be included as a separate cost item during the conceptual phase to ensure that, from the start, it is considered as an important aspect of the software development process.

(4) Program Offices and software quality assurance personnel should communicate before Memoranda of Agreement and Letters of Delegation are written.

AFSCR 800-42, Program Office/AFCMD Interface, was issued on 1 May 1981 and "prescribes the policy for

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establishing program office/AFCMD interface during the conceptual phase and for providing AFCMD specialized support for AFSC program offices throughout the acquisition cycle". This regulation emphasizes that the Air Force recognizes that all appropriate personnel should be involved in the early acquisition phases of systems acquisition.

6.2.2 Specific Recommendations Applicable to the Defense Logistics Agency

(1) Expand DLAM 8200.1, Section IX, Part 15 into a unique software quality assurance guidance document.

(2) Supplement referenced standards and regulations to specifically address software quality assurance. For example, MIL-S-52779A is referenced as a typical specification applicable to computer software data items. Software quality assurance personnel are to determine that the requirements of MIL-S-52779A are met. But there are no details provided to ensure that the requirements are adequately met.

(3) The Procedures Evaluation section of DLAM 8200.1, Section IX, Part 15 should be revised to address software quality assurance procedures.

(4) The Procedures Review section of the above mentioned document should be revised to address the adequacy of contractor's software quality assurance procedures.

6.2.3 Specific Recommendations Applicable to the Electronic Systems Division

(1) Supplement AFR 800-14 with a unique software quality assurance guidance document. Software is addressed by this document but software quality assurance is not.

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(2)   Incorporate software quality assurance functions and ᐧasks into the supplement.

(3)   Revᐧse referenced standards and regulations to specifically address software quality assurance. For example, see 6.2.2 (2).

(4)   Supplement AFSCR 800-42, 7a. to read "in every case establish a formal program office/AFCMD interface for all major or designated systems, etc.".

6.2.4   Specific Recommendations Applicable to the Air Force Contract Management Division

(1)   Expand AFCMDR 74-1, Chapter 15 into a unique software quality assurance guidance document.

(2)   Revise referenced standards and regulations in AFCMDR 74-1, Chapter 15 to specifically address software quality assurance. For example, see 6.2.2 (2).

(3)   Develop a section on software quality assurance for CMSEP.

(4)   Supplement AFSCR 800-42 to require establishment of a history or contract folder starting with involvement at the conceptual phase. This will establish continuity when contract responsibilities are assumed by an AFPRO or DLA organization upon contract award.

(5)   Encourage wider use of AFCMDR 800-1, Contract Management Engineering and AFCMDP 800-2 Contract Management Engineering Guide.

6.2.5   Benefits

(1)   Specification of software quality assurance as a contractual requirement provides for its enforcement throughout software development.

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(2)   Participation of software quality assurance personnel in early system acquisition reduces the possibility of requirements being omitted.

(3)   Improved matching of tasks and personnel resources is ensured through communications between Program Offices and Contract Administration Offices.

(4)   Improved schedule performance is ensured by detailing software quality assurance requirements and tasks in early acquisition phases.

(5)   All of the above should result in cost reduction.

6.2.6 Alternative Recommendations

Electronic Systems Division's Software Acquisition Guidebooks may be adapted by all three organizations. The guidebooks are clearly software oriented and provide detailed procedures for all phases of system development. Again, it is recommended that software quality assurance personnel be involved in early system acquisition phases.

The Defense Logistics Agency's miniaturized version of a consolidated manual, Defense In-Plant Quality Assurance Program, combines in one document all pertinent manuals regarding quality assurance. Again, this manual is hardware oriented. The same type of manual should be prepared for software to include more detail based on software principles rather than adapting hardware procedures to software.

The Electronic Systems Division can prepare the same type of consolidated manual combining AFR 800-14 with all referenced regulations and specifications regarding software. A combination of this manual and the Software Acquisition Guidebooks would foster an effective management program.

The Air Force Contract Management Division can prepare a consolidated manual including Chapter 15 of AFCMDR 74-1,

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AFCMDR 800-1, AFCMDP 800-2, other referenced regulations and specifications on software, and CMSEP with the addition of questions specifically geared to software quality assurance. A consolidated manual will provide the software quality assurance staff with basic information and reduce time spent in document search. The next step would be to revise the documents to include more detail based on software.

6.3 RECOMMENDATIONS FOR IMPROVEMENT OF THE RELATION OF SOFTWARE QUALITY ASSURANCE TO SOFTWARE DEVELOPMENT

Software quality assurance is an integral part of the software development process. This must be reflected in the life cycle planning. Software quality assurance activities must be planned with the same precision and concern as every other detail of software development. If not, there is no reason for its existence. Quality does not just happen. It is the result of such things as rigid control, frequent assessment through reviews and audits, and pre-planned corrective action procedures.

Specifically, some of the functions covered by software quality assurance are:

- Ensuring that sound software development practices are followed throughout the software development life cycle,

- Establishing software quality assurance evaluation procedures,

- Developing tools and techniques tailored for monitoring contractor reviews and audits,

- Monitoring the review of all acceptance test plans and procedures.

6.3.1 General Recommendations

Based on the above criteria, the following recommendations are made for improving the relation of software quality assurance to software development. These recommendations apply to the Defense Logistics Agency, the

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Electronic Systems Division and the Air Force Contract
Management Division.

(1) Integrate software quality assurance activities
into every phase of life cycle models and
development.

(2) Develop model documentation standard formats
for writing documents.

(3) Develop standard checklists specifically for
monitoring software quality assurance audits
and reviews.

(4) Develop procedures that are independent of hard-
ware oriented procedures.

6.3.2 Specific Recommendation Applicable to the Defense
Logistics Agency

(1) A major review of the life cycle model should
be undertaken by the Defense Logistics Agency
to be consistent with the one used within DoD.
This model is accepted by industry.

6.3.3 Benefits

(1) Life cycle models with software quality assur-
ance activities integrated can serve as guides
for planning. Requirements, procedures, and
documentation required by each contract will be
inserted into the appropriate areas of the life
cycle phase. From this point, detailed planning
can take place with negligible chance of im-
portant areas being omitted.

(2) Software quality assurance personnel may be re-
sponsible for several projects, all of which may
be proceeding through different phases. Fully
developed life cycle models with integrated
software quality assurance activities, provide
a method of keeping track of which activities
are to be performed, and reports that are to be

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written for each project. By using this
tracking system, the software quality assurance
staff can plan and use time efficiently and,
again, less danger exists of important areas
being omitted.

(3)   A life cycle model as described provides a sig-
nificantly practical tool for training software
quality assurance personnel. Transfer of know-
ledge from the training setting to the world of
everyday activities will be facilitated by the
use of a tool that depicts standard procedures
in software development projects.

(4)   Since the system of controls for software
quality assurance is based primarily on documen-
tation review, model documents will serve
as guides for documentation preparation.

(5)   Tools tailor made for specific contracts will
address software quality requirements and elim-
inate the use of standard hardware quality
procedures.

6.3.4 Alternative Recommendations

(1)   AFCMD's Contractor Management Self Evaluation
Plan (CMSEP) is a technique that can be adapted
by the Defense Logistics Agency and the Elec-
tronic Systems Division. This plan is highly
structured and provides a tracking system for
evaluating contractors' fulfillment of contrac-
tual requirements. Again, include a section
specifically written for software quality
assurance.

(2)   Electronic Systems Division uses checklists
modeled on Data Item Descriptions (DIDs) and
Standards. Work on consolidation of all

checklists has also begun. These efforts can be undertaken by the Defense Logistics Agency and the Air Force Contract Management Division.

6.4 RECOMMENDATIONS FOR IMPROVEMENT OF COMMUNICATION METHODS AND MODEL DOCUMENTS

Many communications fail because of inadequate planning. Good planning must consider the responsibilities of those who will receive the communications and those who will be affected by it. While communications may be aimed primarily at meeting the demands of an immediate situation, they must be consistent with long-range objectives.

The following guides are presented to aid in developing effective communication:

- Determine the purpose of the communication;

- Develop a system of communication flow to be followed during project implementation;

- Determine appropriate guidelines and regulations; and

- Ensure that all affected project personnel are made aware of the communication system.

6.4.1 General Recommendations

Based on the above criteria, the following recommendations are made for improving communication methods and model documents within and among organizations. These recommendations apply to the Defense Logistics Agency, the Electronics Systems Division and the Air Force Contract Management Division.

(1) Determine formal and informal methods of communication.

(2) For written communications, develop model communication documents.

(3) Determine which communications are to be maintained as records.

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(4) Develop a tracking system for communication flow.

(5) Determine the requirements for frequency of communications.

6.4.2 Specific Recommendations: None

6.4.3 Benefits

(1) Model communication documents will be uniform and consistent throughout the organization, formatted and prepared for use so that information is brief but complete.

(2) Maintaining records ensures that all personnel have access to relevant information and new personnel can be updated concerning significant events in project performance.

(3) A tracking system will ensure that all personnel receive communications that affect their activities, and are aware of who is to receive reports, letters, etc. that they, in turn, are required to submit.

(4) Determining the frequency of communications aids personnel in preparing beforehand for conferences and meetings and encourages the maintenance of records that may be the subject of the meeting.

6.4.4 Alternative Recommendations: None

6.5 RECOMMENDATIONS FOR IMPROVEMENT OF TRAINING AND STAFFING

The key factor in assuring the quality of software is professionally trained personnel who operate as a separate group within an organization. Hardware and software are integrated; one cannot run without the other. Hardware quality assurance and software quality assurance groups must integrate the results of their activities but the performance of activities requires the use of different plans and procedures.

Software literature emphasizes the fact that future quality groups may combine software quality assurance and hardware quality assurance into one total quality assurance organization. For the present, SAI recommends the formation of separate groups. Software quality assurance groups should operate independently, develop unique software quality assurance guidance documents and evaluation procedures, develop specific regulations and standards, and employ personnel technically on a par with their hardware quality assurance counterparts. When software quality assurance is recognized as equally important and functions as a unique discipline, then integration can occur.

6.5.1 General Recommendations

Based on these considerations, the Defense Logistics Agency, the Electronic Systems Division and the Air Force Contract Management Division are encouraged to maintain and strengthen separate software quality assurance organizations. To this end, the following recommendations are made for improvements in training and staffing.

(1) Provide training in the management of software projects and in basic software engineering principles.

(2) Make training available to more personnel.

(3) Develop programs for certification.

(4) Orient personnel to specific contractor organizations, procedures and communication methods.

6.5.2 Specific Recommendations Applicable to the Defense Logistics Agency

(1) In the revision of DLAM 8220.4 which DLA is undertaking, include courses on integration of software quality assurance activities with the software development life cycle.

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(2)   Supplement DLAM 8220.5, Quality Assurance Intern
      Program to include software quality assurance.

6.5.3   Specific Recommendations Applicable to the Electronic
        Systems Division and the Air Force Contract
        Management Division

(1)   Investigate adoption of the Defense Logistics
      Agency's Quality Assurance Certification Program
      DLAM 8220.4, and Quality Assurance Intern Pro-
      gram DLAM 8220.5.

(2)   Supplement both of the above programs to in-
      clude software quality assurance if this has
      not been done.

6.5.4   Benefits

(1)   Training in the use of software design and
      development tools and techniques will enable
      personnel to perform software quality assurance
      functions as a group separate from and indepen-
      dent of any other group.

(2)   Certification programs strengthen the profession-
      al level of project staff. With the increase in
      emphasis on software quality assurance, RFPs may
      specify that certified contractor software
      quality assurance professionals must be assigned
      to software development projects. Government
      software quality assurance personnel should
      possess the same qualifications.

(3)   Orientation instructions ensure that personnel
      are familiarized with the organization and its
      procedures.

(4)   Trained software quality assurance personnel can
      perform activities with skill and confidence,
      and ensure that projects are completed within
      time and cost constraints.

6.5.5 Alternative Recommendations

Training cannot be made available to all personnel except over a long period of time. In the interim, and where possible, less experienced personnel can be afforded the opportunity to work on a daily basis with experienced government software quality assurance managers.

6.6 CONCLUSIONS

Greater quality of software can be expected from software quality assurance guidance documents that treat software quality assurance as a unique discipline, software life cycle development that integrates software quality assurance activities, communication methods that are structured yet flexible, and personnel who receive the training needed to assist them in the performance of their work.

Implementation of these recommendations will provide DLA, ESD and AFCMD with an increased probability of receiving and maintaining quality software.

APPENDIX A

TRAINING COURSE OUTLINE
FOR IMPROVING
SOFTWARE QUALITY ASSURANCE

METHODOLOGY FOR IMPLEMENTING TRAINING COURSE

Overview

This Training Course Outline was prepared by Systems Architects, Incorporated (SAI). It is designed to cover the major topics of Software Quality Assurance (SQA) for Air Force/Electronic Systems Division contracts. The course is introductory in nature, and upon completion, students should be familiar with terminology, contractual requirements, regulations, specifications and standards concerning software quality assurance. The study should acquire a basic familiarity with and appreciation for SQA, and a knowledge of where to turn for further information.

Suggested Approach

This outline defines a stand alone course. The material should take approximately eighty (80) hours to cover. With the exception of Section 6.0, sections have been broken down to at least three levels. Further subdivisions will occur during actual instruction.

Prerequisites

Students should have some familiarity with software (such as programming experience) and some familiarity with the organization through an orientation and, if possible, some on-the-job training.

Materials

Students should be provided with hard copies of materials prior to discussion. This primarily includes software-related documents; for example, those documents listed in Section 2.0 (2.2). Overhead slides or handouts which emphasize the important points should be prepared.

Course Overview

Section 1.0 -- Software Development Throughout the Software
Life Cycle

This section is an introduction to the software life cycle
and highlights important software development activities related
chronologically to the life cycle. The life cycle will be the
central reference throughout the training course; it should be
appropriately emphasized.

Section 2.0 -- Software Quality Assurance Requirements

This section begins with an introduction to SQA and how it
relates to and supports software development throughout the life
cycle. It introduces important documents, directed at SQA. Also
introduced are software reviews and audits, which form the back-
bone of SQA activities.

Section 3.0 -- Preparation for Contract Award and Monitoring

This section covers activities up to and including contract
award. Discussions include the Request for Proposal and its com-
ponents, delegation of responsibilities to the CAO prior to
contract award, documents guiding pre-award and source selection
activities, and the contract award activities.

Section 4.0 -- Contract Administration

This section covers contract administration activities. It
encompasses a discussion of documents dealing with configuration
management, procedures for evaluating progress throughout the
contract, a discussion of procedures to report schedule deficien-
cies or major changes, and a discussion of validation procedures
and their advantages and disadvantages. Finally, the most fre-
quent forms of documentation should be highlighted along with a
discussion of who is responsible for their preparation and who
reviews them.

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Section 5.0 -- SQA Within the Government Organizations

At this point, software quality assurance is discussed more specifically in the context of the government organization. First a brief introduction should be given regarding Air Force SQA responsibilities and how they relate to the particular organization. Next is a detailed study of SQA in the particular organization.

Section 6.0 -- SQA Within the Contractor Organization

Contractor responsibilities regarding SQA are discussed. Activities that are generally part of the contractor's management plan for software quality assurance are covered and should be correlated to the government's procedures for monitoring these plans.

Section 7.0 -- Communications

This section will include discussions on formal and informal communication methods, oral and written. Its purpose will be to clearly define the communication network and key points of reference. Also covered will be important communications reports, and people responsible for their preparation and review. The goal of this section is to familiarize students with where to turn for information, and to make them aware of their communications responsibilities. This includes communications within the government organization, among the government organizations (including the Administrative Contracting Offices) and with the contractor.

Section 8.0 -- Modern Software Engineering Tools and Techniques

This section describes modern tools which aid software development and quality assurance throughout the life cycle. Some examples are given, but emphasis should be placed on the different types of tools which are useful in each phase of the life cycle, and their uses. Some software development techniques are included as examples. This section can be adapted to include techniques most often used in Air Force software development programs.

Section 9.0 -- Workshop

This section is the culmination of the course, and is intended to be taught in a workshop format. It draws upon knowledge gained in the first seven sections. Students will be given an opportunity to develop a typical SQA program from the conceptual phase through the operational phase. The SQA program will be developed based on a sample software development contract.

1.0 SOFTWARE DEVELOPMENT PLAN THROUGHOUT THE SOFTWARE LIFE CYCLE

1.1 Requirements Analysis Phase

    1.1.1 Program Management Directive (PMD)

    1.1.2 Program Management Plan (PMP)

    1.1.3 Test and Evaluation Master Plan (TEMP)

    1.1.4 Computer Resources Integrated Support Plan (CRISP)

    1.1.5 Systems Specifications

    1.1.6 Systems Requirements Review (SSR)

    1.1.7 Systems Design Review (SDR)

1.2 Preliminary Design

    1.2.1 Computer Program Configuration Item (CPCI)

    1.2.2 Part I Computer Program Development Specifications

    1.2.3 Preliminary Design Review (PDR)

    1.2.4 CPCI Test Plan

1.3 Detail Design

    1.3.1 Draft Part II Computer Program Product Specifications

    1.3.2 Critical Design Review (CDR)

    1.3.3 Part II Specifications and Test Procedures

1.4 Code and Checkout

    1.4.1 Computer Program Test and Evaluation (CPT & E)

    1.4.2 Altered Product Specifications

    1.4.3 Preliminary Qualifying Test (PQT) Reports

1.5 Test and Integration

    1.5.1 Formal Qualification Test (FQT)

    1.5.2 CPCI Adaptation, Installation and Checkout

    1.5.3 CPCI Qualification Final Report

    1.5.4 Functional Configuration Audit (FCA)

    1.5.5 Physical Configuration Audit (PCA)

    1.5.6 Formal Qualification Review (FQR)

    1.5.7 Development Test and Evaluation (DT&E)

    1.5.8 Initial Operation Test and Evaluation (IOT & E)

    1.5.9 Program Management Responsibility Transfer (PMRT)

1.6 Operation and Support

    1.6.1 Follow-on Operational Test & Evaluation
        (FOT & E)

2.0 <u>SOFTWARE QUALITY ASSURANCE REQUIREMENTS</u>

2.1 Interrelation of Software *Development and Software*
    Quality Assurance

    2.1.1 How Software Quality Assurance and Software
        Development Activities Integrate Into the
        Life Cycle Model

    2.1.2 Assurance That Software Complies With Design
        and Performance Requirements

    2.1.3 Reduction of Schedule Slippages By Early
        Problem Identification and Isolation

    2.1.4 Systematic Recording, Reporting, and Tracking
        Software Problems to Assure That Prompt
        Corrective Actions Are Taken

2.2 Documents Directed at SQA

    2.2.1 Management Plans

        2.2.1.1 AFR 800-14
               Vol. I - <u>Management of Computer</u>
                       <u>Resources in Systems</u>
               Vol. II- <u>Acquisition and Support</u>
                       <u>Procedures for Computer</u>
                       <u>Resources in Systems</u>

        2.2.1.2 AFCMDR 74-1 <u>Procurement Quality</u>
               <u>Assurance Program</u>

        2.2.1.3 AFCMDR 178-1 <u>Contractor Management</u>
               <u>System Evaluation Program</u>

        2.2.1.4 DLAM 8200.1 <u>Procurement Quality</u>
               <u>Assurance</u>

        2.2.1.5 Computer Program Development Plans

    2.2.2 Software Quality Guidance Documents

        2.2.2.1 MIL-S-52779A <u>Software Quality</u>
               <u>Assurance Program Requirements</u>

        2.2.2.2 AFR 74-1, Chapter 15 "Computer
               Software Quality Assurance Program"

7.4 Formal Oral Communications

    7.4.1 Meetings, Panel Discussions

    7.4.2 Training Sessions, Classes, Orientations

    7.4.3 Briefings, Speeches

7.5 Informal Written Communications

    7.5.1 Notes, Informal Memoranda

    7.5.2 Suggestions, Grievances

7.6 Informal Oral Communications

    7.6.1 Face-to-face Discussions

    7.6.2 Telephoning

    7.6.3 Work Groups

8.0 MODERN SOFTWARE ENGINEERING TOOLS AND TECHNIQUES

8.1 Automated Test Tools Throughout The Software Development Process

    8.1.1 Requirement Analysis/Preliminary Design

        8.1.1.1 Automated Design Tools (Methodology for Stating Requirements for Design). Examples of this include CADSAT (USAF), DQM (Hughes) and MEDL-R (Martin Marietta)

        8.1.1.2 Automated Simulation Tools (Model the Hardware/Software of the System to Study its Characteristics). An example is AISIM (Hughes)

    8.1.2 Detail Design, Coding and Checkout

        8.1.2.1 Code Analysis Tools (To Find Syntax Errors and Error-prone Constructions)

        8.1.2.2 Structure Analysis (To Look for Structural Flaws)

        8.1.2.3 Module Interface Checks (Find Inconsistencies in Declaration of Data Structures and Check Module Linkage) ARGUS MICRO (Boeing) is an Example of This

        8.1.2.4 Check Sequence of Events (e.g., Order of Input/Output Sequences, etc.)

8.1.3 Test and Verification

    8.1.3.1 Monitor Run-Time Behavior (To Collect Execution Statistics)

    8.1.3.2 Automated Test Case Generation (To Provide Testers with Best Test Cases for Each System)

8.1.4 Performance Factors (Prior to Installation)

    8.1.4.1 Program Restructuring Tools (Assist Program Reorganization for Optimization)

    8.1.4.2 Validation of Parallel Operations (To Evaluate Efficiency of Parallel Processing Schedule)

8.1.5 Maintenance and Documentation

    8.1.5.1 Documentation Generation (Highlights Code and Structure Information Pertinent to Documentation) Examples Include TRANSFOR (Boeing), GIRAFF (USAF), and COMMON (Naval R & D Center)

    8.1.5.2 Evaluation of Modification (To Predict Effects of Proposed Changes)

8.1.6 Software Quality Validation Tools (Compare Program Attributes to a Set of Desirable Characteristic Attributes) An Example is METRICS (GE)

8.2 Software Development Techniques

8.2.1 Structured Programming

    8.2.1.1 Top-Down Design

    8.2.1.2 Structured Design

8.2.2 Control Structures

    8.2.2.1 Sequence Structure

    8.2.2.2 Selection Structure

    8.2.2.3 Iteration Structure

    8.2.2.4 Exit Structure

8.2.3 Techniques

    8.2.3.1 Flowcharts

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